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Volume 5 | Technical Appendices

CFA25 | Castle Bromwich and Bromford

Flood risk assessment (WR-003-025)

Water resources

November 2013

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Appendix WR-003-025

Environmental topic:	Water resources and flood risk assessment	WR
Appendix name:	Flood risk assessment	003
Community forum area:	Castle Bromwich and Bromford	025

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1 Introduction

1.1 Structure of the water resources and flood risk assessment appendices

1.1.1 The water resources and flood risk assessment appendices comprise five parts. The first of these is a route-wide appendix (see Volume 5: Appendix WR-001-000).

1.1.2 Additional specific appendices for each community forum area are also provided. For the Castle Bromwich and Bromford area (CFA25) these are:

- a water resources assessment (see Volume 5: Appendix WR-002-025);
- a flood risk assessment (i.e. this appendix);
- a hydraulic modelling report for the River Tame (see Volume 5: Appendix WR-004-019); and
- a groundwater modelling report for the Bromford tunnel portals (see Volume 5: Appendix WR-004-020).

1.1.3 Maps referred to throughout the water resources and flood risk assessment appendices are contained in the Volume 5 water resources map book.

1.2 Scope of this assessment

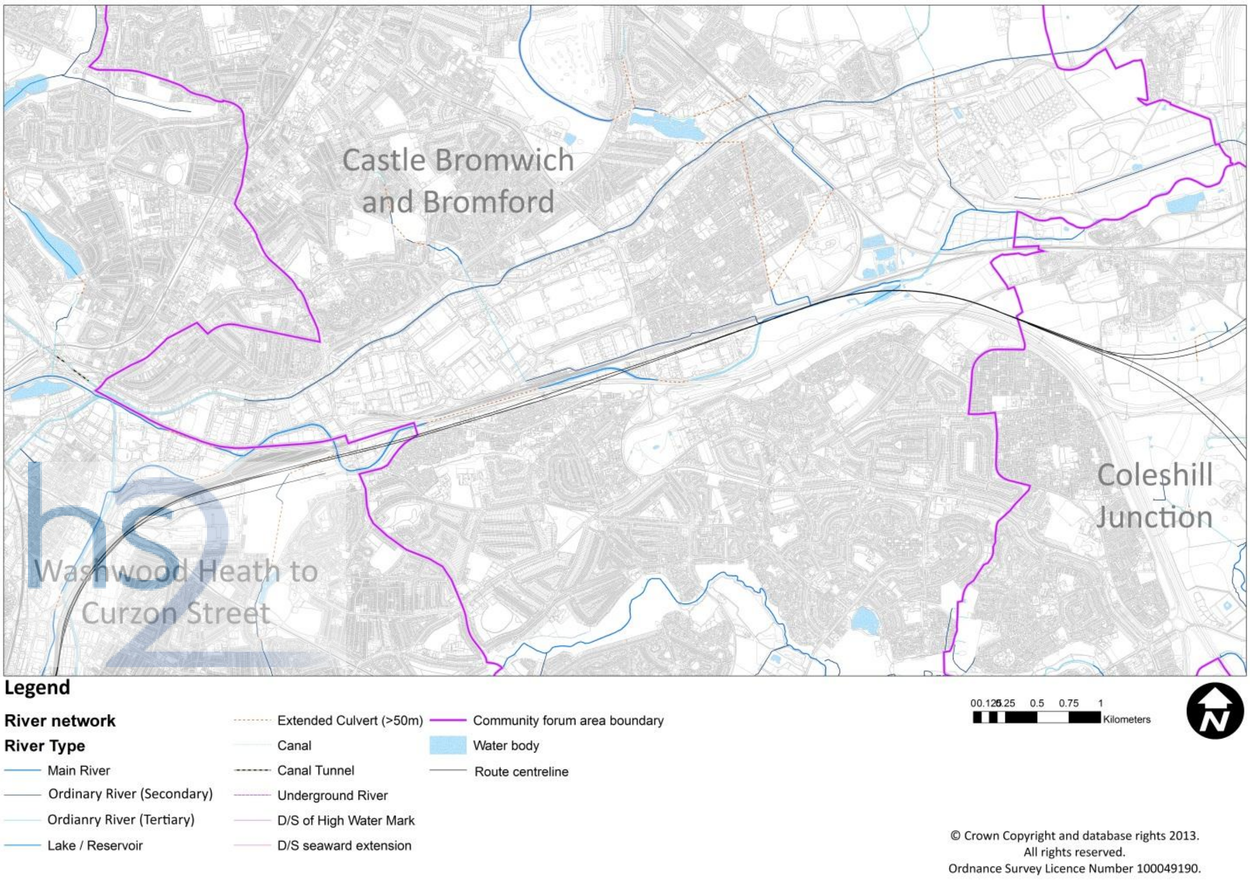
1.2.1 This flood risk assessment (FRA) considers the assessment of flood risk in the Castle Bromwich and Bromford CFA. This FRA is based on the Proposed Scheme as shown in Volume 2: Map book CT-06. Its purpose is to document how flood risk has been assessed and managed at this stage of the project's development so as to inform the hybrid Bill. It can be anticipated that the details of flood risk management will develop further as the project proceeds through later stages of design. The assessment has been carried out in accordance with the requirements of the National Planning Policy Framework (NPPF)[1], which aims to prevent inappropriate development in areas at risk of flooding and to ensure that, where development is necessary in areas at risk of flooding, it can occur without risk to the development or to third parties.

1.3 Location

1.3.1 This report focuses on CFA25 Castle Bromwich and Bromford. The area of consideration is shown in Figure 1.

[1] Department for Communities and Local Government (2012) *National Planning Policy Framework*

Figure 1: Castle Bromwich and Bromford CFA25



2 Flood risk assessment methodology

2.1.1 The aim of this FRA is to assess the risk of all forms of flooding to and from the development. A risk-based methodology has been adopted through the application of the source-pathway-receptor (SPR) model.

2.2 Source-pathway-receptor model

2.2.1 Flood risk is assessed using the source-pathway-receptor model. In this model, individual sources of flooding within the study area are identified. The primary source of flooding is rainfall, which is a direct source in the short-term (surface water flooding) and can lead to flooding from watercourses (river flooding) and overloaded man-made collection systems (sewer flooding) in the short or medium term. Stored rainfall, either naturally in below ground aquifers and natural lakes or artificially in impounded reservoirs and canals can lead to flooding when the storage capacity of the system is exceeded. A final source of flooding arises from tidal effects and storm surges caused by low pressure systems over the sea.

2.2.2 The identification of the flooding source and pathway is based on a review of local conditions and consideration of the effects of climate change (CC).

2.2.3 For there to be a risk of flooding at an individual receptor there must be a pathway linking it to the source of flooding. The pathways within the study area are assessed by reviewing national datasets that show the spatial distribution of flood risk. Taking this into account, the associated magnitude of risk is then categorised.

2.2.4 Receptors include people, properties, businesses, infrastructure, the built and the natural environment which is within the range of the flood source, and is connected to the source of flooding by a pathway. The Proposed Scheme includes all associated temporary and permanent infrastructure.

2.2.5 This FRA presents baseline (current day) flood risk and post-development flood risk as a result of the Proposed Scheme. Areas of interest are identified through comparison of the national spatial datasets with the design drawings. Where a risk is identified, mitigation is proposed in line with recommendations in the NPPF.

2.2.6 Existing development within the study area is identified using Ordnance Survey (OS) mapping information and a high level assessment has been undertaken to identify receptors that are within or in close proximity to an area of flood risk via pathways. The vulnerability of each receptor is classified using Table 2 of the NPPF Technical Guidance Document[2].

2.2.7 The assessment then considers the vulnerability of the receptor with reference to the flood risk category of the source using Table 3 of the NPPF Technical Guidance Document and assesses whether the Proposed Scheme has any potential to influence or alter the risk of flooding to each receptor. The Proposed Scheme is committed to ensuring that there is no adverse effect on the risk of flooding to third party receptors, and therefore, where such potential exists, mitigation is proposed based on further analysis.

[2] Department for Communities and Local Government (2012) *National Planning Policy Framework Technical Guidance*

2.2.8 The FRA has been written to demonstrate the relative change in flood risk as a result of the Proposed Scheme. Whilst all change in risk status is highlighted, the focus of this document is on the change in risk status to identified local receptors, particularly existing infrastructure.

2.3 Flood risk categories

2.3.1 The level of flood risk is categorised by assessing the design elements against the datasets for each source. A matrix showing the flood risk category associated with each flooding source is presented in Table 1.

Table 1: Flood risk category matrix for all flooding sources

Source of flooding	Flood risk category				
	No risk	**Low**	**Medium**	**High**	**Very high**
Watercourse[3]	-	Flood Zone 1	Flood Zone 2	Flood Zone 3a	Flood Zone 3b
Surface water / overland flow[4]	No FMfSW	FMfSW <0.3m for 1 in 200 year event	FMfSW >0.3m for 1 in 200 year event and FMfSW <0.3m for 1 in 30 year event	FMfSW >0.3m for 1 in 30 year event	-
Groundwater[5]	-	Very low-low	Moderate	High-very high	-
Drainage and sewer systems[6]	No sewer in vicinity of site	Surcharge point >20m from site and no pathways	Surcharge point within 20m of site and restricted pathways	Sewer network crosses site and pathways exist	-
Artificial sources[7]	Outside of inundation mapping / no pathway exists	Within inundation mapping / pathway exists	-	-	-

2.4 Exclusions and limitations

2.4.1 Temporary works have not been assessed unless they are of a significant scale compared with the post-construction scheme or are subject to or pose a significant flood risk or change in risk.

2.4.2 The assessment has been carried out in accordance with the requirements of the National Planning Policy Framework (NPPF)[8], which aims to prevent inappropriate development in areas at risk of flooding and to ensure that, where development is necessary in areas at risk of flooding, it is safe without increasing flood risk elsewhere.

[3] River flood risk taken from the Environment Agency Flood Zone mapping or hydraulic modelling carried out for this FRA.

[4] Surface water flood risk taken from the Environment Agency Flood Maps for Surface Water (FMfSW).

[5] Groundwater flood risk taken from local flood risk assessment reports.

[6] Identified using the Severn Trent Water's assets network.

[7] Risk from reservoir flooding identified using the Environment Agency Reservoir Inundation mapping, canal flooding taken from identifying proximity of the Proposed Scheme to canals from Ordnance Survey mapping.

[8] Department for Communities and Local Government (2012) *National Planning Policy Framework*

2.4.3 Updates on the river models provided by the Environment Agency for use on this project were carried out (and detailed in the accompanying hydraulic modelling report Volume 5: Appendix WR-004-019).Therefore, the flood mapping data provided in this FRA differs from the mapped outlines available from the Environment Agency. The updated models and flood extents should only be viewed in the context of assessing flood risk related to the Proposed Scheme.

2.4.4 This FRA (and accompanying appendices) will require updating as the design develops and a greater level of detailed data (e.g. topographical survey) become available.

3 Design criteria

3.1 Source of design criteria

3.1.1 This FRA has taken account of the following documents:

- NPPF;
- Highways Agency Design Manual for Roads and Bridges (1992)[9];
- National Sustainable Drainage Systems (SuDS) Working Group Interim Code of Practice (2009)[10]; and
- CIRIA Report C689 - Culvert Design and Operation Guide (2010)[11].

3.1.2 The key design criteria applied to the project are summarised below.

3.2 Summary of principal design criteria

Flood risk to third parties

3.2.2 The design has set out to avoid significant increases in flood risk to third parties, as a result of the Proposed Scheme up to and including the 1% Annual Exceedence Probability (AEP) flood event plus an appropriate allowance for climate change (cc) which has been abbreviated to 1% AEP+CC within this report.

Climate change

3.2.3 Climate change allowance is in accordance with NPPF.

3.2.4 Increases in peak rainfall intensity and peak river flow as a result of climate change have been allowed for as per the period 2085 to 2115 as defined in Table 5 of the Technical guidance to the NPPF and shown in Table 2 below.

Table 2: Appropriate climate change allowance figures for rainfall intensity and peak river flow (extract from Table 5 in Technical Guidance of the NPPF)

Parameter	1990 - 2025	2025 - 2055	2055 - 2085	2085 - 2115
Peak rainfall intensity.	+5%	+10%	+20%	+30%
Peak river flow.	+10%	+20%		

3.2.5 There is one departure to this; a 30% increase in flow in ungauged catchments has been used in order to account for uncertainty in flow calculations. This approach has been applied only when assessing culverts on small watercourses where no hydraulic modelling has been undertaken.

[9] Highways Agency (1992), *Design Manual for Roads and Bridges for trunk roads*

[10] National Sustainable Drainage Systems (SuDS) Working Group (2009), *SuDS Interim Code of Practice*

[11] CIRIA Report C689 (2010), *Culvert Design and Operation Guide*

Freeboard at bridges

3.2.6 A minimum of 600mm freeboard above the 1% AEP+CC flood event has been allowed to the soffit of all bridges and viaducts. On main rivers, where possible, a freeboard of 1000mm has been allowed.

Freeboard at culverts

3.2.7 The freeboard provided between the 1% AEP+CC water level and the soffit of any proposed culvert is a minimum of 300mm for ordinary watercourses and 600mm for main rivers. The exception to this is where new structures are sized to match existing.

Flood protection to the Proposed Scheme rail infrastructure

3.2.8 The Proposed Scheme rail infrastructure (including the track drainage systems) will be designed to be protected against inundation in the 0.1% AEP flood event for both river and surface water flooding. This will be achieved through ensuring either a of 1m between the rail level and the 0.1% AEP flood level, or by providing flood protection with a freeboard of at least 300mm above the 0.1% AEP flood level.

Attenuation of surface run-off

3.2.9 All drainage will be attenuated in order that peak surface run off from the Proposed Scheme in the events up to the 1% AEP+CC peak rainfall event is no greater than the existing current day baseline run-off under the same peak rainfall event.

4 Data sources

4.1.1 The following data sources have been referred to in the compilation of this document:

- Environment Agency web site; http://www.environment-agency.gov.uk/;
- reservoir flood mapping[12];
- generalised river flood mapping and flood zone mapping[13];
- existing river models of the River Tame and Plants Brook;
- Birmingham City Council (BCC) Level 1 Strategic Flood Risk Assessment (SFRA), January 2012[14];
- historic flooding records[15];
- BCC Preliminary Flood Risk Assessment, May 2011[16];
- Flood map for surface water (FMfSW)[17];
- topographic survey (200mm grid resolution laser interferometry detection and ranging (LiDAR) survey, in digital terrain model and digital surface model format) and associated aerial photography;
- as built and historic drawings and land drainage records from Network Rail (NR), BCC & others;
- evidence gathered from site visits (including photographs);
- online photographic & mapping resources (Google maps, Bing maps etc);
- Ordnance Survey 1: 10,000; 1:25,000 and 1:50,000 mapping;
- publicly available planning applications from recent developments within the area of interest;
- sewer network data from Severn Trent Water Plc (STW)[18];
- British Geological Survey (BGS) mapping;
- geotechnical desk studies; and
- Powell et al (2000)[19]: Geology of the Birmingham area.

[12] Environment Agency (2012), *Lakes and reservoirs GIS layer*

[13] Environment Agency (2012), *Flood zone mapping GIS layer*

[14] Atkins (2012). Birmingham City Council. *Strategic Flood Risk Assessment updated*

[15] Environment Agency (2012), *Midlands Historical 1992 and 2007 flood event GIS layers*

[16] Birmingham City Council (2011), *Birmingham City Council Preliminary Flood Risk Assessment*

[17] Environment Agency (2012), *Midlands Flood Map for Surface water GIS layers*

[18] Severn Trent Water (2012), *Utilities GIS Data*

[19] Powell, JH, Glover, BW, and Waters, CN. (2000),. *Geology of the Birmingham area. Memoir of the British Geological Survey, Sheet* 168 (England and Wales).

4.2 Site familiarisation visits

4.2.1 Site familiarisation visits have been carried out for key locations along the route where access has been granted. This included four visits to Park Hall nature reserve and two visits to Bromford, including a site visit to the reach of the River Tame below the M6 viaduct.

5 The proposed development

5.1.1 The route of the Proposed Scheme through this area is approximately 5.1km long and will commence at the BCC and NWBC administrative area boundaries, just south of the B4118 Birmingham Road, north of Chelmsley Wood. The route will run west, initially in a deep cutting through higher ground, and then emerging onto a viaduct across the valley floor and the diverted River Tame. The route will then continue on embankment across the extended Plants Brook and Dunlop Channel, typically 10-15m south of the Birmingham and Derby line, near its junction with the line which runs towards Sutton Coldfield.

5.1.2 The route will then descend to below ground level initially in a cutting with retaining walls, before entering a tunnel, the portal of which will be situated 300m east of the A452 Chester Road.

5.1.3 The tunnel will pass below the A452 Chester Road, under the River Tame, the M6 and Bromford Drive. At this point, the route (still in tunnel) will leave the Castle Bromwich and Bromford area (the remaining part of the tunnel is described in the Washwood Heath to Curzon Street CFA26 report). The entire length of the tunnel from Castle Bromwich Business Park to the Drew's Lane Industrial Estate will be 2.9km (see Volume 2: Maps CT-06-135 to CT-06-138a).

5.2 Design elements

5.2.1 To facilitate the Proposed Scheme the following design elements are required:

- high speed rail lines;
- overhead electrification gantries;
- signals;
- sections of route and side road diversions on embankment;
- sections of route and side road diversions in cutting;
- viaducts and overbridges spanning urban areas, rural land, highways, railways, watercourses and canals;
- bridges under existing urban areas, rail and highway infrastructure;
- flood relief culverts;
- culverts for existing watercourses;
- river diversions;
- tunnel; and
- drainage infrastructure.

5.2.2 Within CFA25 the following elements have direct relevance to the assessment of flood risk:

- surface water drainage;
- new drainage provision for highway diversions;
- tunnel allowing the route to run under the Bromford area;
- diversion of the River Tame within Park Hall nature reserve including new connections to

the Dunlop Channel and Plants Brook;

- viaduct crossing of the River Tame and its floodplain within Park Hall nature reserve; and
- the route will be on embankment over part of the current River Tame corridor adjacent to Park Hall nature reserve.

6 Existing flood risk

6.1 River flood risk

6.1.1 River flood risk is the risk of flooding posed by rivers and streams. The river flood risk within CFA25 is dictated by the risk posed by the River Tame and the interaction of its tributaries.

River Tame

6.1.2 The River Tame is the most significant watercourse in the West Midlands conurbation and drains a total catchment up to Alrewas of 1500km^2 (as taken from the Flood Estimation Handbook (FEH) CD Rom[20]) before discharging into the River Trent at Alrewas. The Tame catchment to Washwood Heath is approximately 350km^2. The majority of the catchment is heavily urbanised and the channel has been extensively modified for a large proportion of its length.

6.1.3 It is a main river and therefore regulatory control is with the Environment Agency, although riparian landowners do have a responsibilities to manage the river where it passes through their land and are restricted on the activities they can perform within or adjacent to the river without consent from the Environment Agency.

6.1.4 Local to the route but within CFA26 (see Volume 5: Appendix WR-003-026), the River Tame flows along the north eastern boundary of the Star City commercial development. It is then joined by the River Rea and flows eastwards through more industrial and commercial areas such as Hurricane Park in a channel with natural banks and bed with some localised hard engineered reinforcement. The river then loops to the south and flows underneath the M6, the A47 Heartlands Parkway and the Derby to Birmingham Line into CFA25.

6.1.5 Bromford Lane passes over the river as it begins to loop northwards. It then orientates eastwards and flows under the M6 between the residential area of Bromford to the south and the Derby to Birmingham Line, the Heartland Parkway and an extensive area of industrial development to the north. At this point the channel becomes a two stage fully lined concrete channel with the piers supporting the M6 located in the middle of the channel. The motorway veers south away from the river after approximately 1km but the river and motorway converge at A542 Chester Road and the river is once more located under the M6 viaduct downstream of A452 Chester Road for a short length.

6.1.6 Once the river emerges from the M6 for the second time it passes south of Castle Bromwich Business Park and an industrial area to the south of Castle Vale. It then enters Park Hall nature reserve in a more natural but still modified channel.

[20] Centre for Ecology and Hydrology (1999), *Flood Estimation Handbook (FEH)*

6.1.7 In order to establish the existing flood risk posed by the River Tame to the land located along (and adjacent to) the Proposed Scheme, reference has initially been made to the existing flood zone mapping available from the Environment Agency[21] and reproduced in the Volume 5: Map book WR-01.

6.1.8 This indicates that the following locations are in Flood Zone 3 and as such are at high risk from inundation from the River Tame:

- the east boundary of Hurricane Park;
- the central section of Bromford Lane/A47 Heartlands Parkway roundabout;
- sections of the Derby to Birmingham Line where the railway runs adjacent to the M6 and the Tame is under the M6;
- extensive inundation of residential properties in Bromford and Castle Vale;
- the Derby to Birmingham Line local to Castle Bromwich Business Park;
- Park Hall nature reserve;
- the Derby to Birmingham Line local to Park Hall nature reserve; and
- the southern extent of Minworth waste water treatment works.

6.1.9 The areas at medium risk (Flood Zone 2) are indicated to include the following. These are all high vulnerability land uses and the impact of flooding would have a significant effect on both the land owners/operators in terms of the cost incurred and the water environment in terms of water quality implications :

- an existing oil depot;
- the industrial area east of Bromford; and
- a larger area of Castle Vale.

6.1.10 In order to fully understand the existing risk posed by the river and to be able to evaluate the impact of the Proposed Scheme on the hydraulic behaviour of the River Tame, the following river hydraulic models have been obtained from the Environment Agency:

- 1D ISIS Strategic Flood Risk Management (SFRM) river hydraulic model; and
- 1D/2D ISIS - Tuflow Central Visualisation river hydraulic model.

6.1.11 The 1D ISIS SFRM model is a detailed 1D model of the River Tame catchment.

6.1.12 Hydrological inputs are included based on detailed analysis of observed event data. These are included within the hydraulic models as hydrographs and the model ran in an unsteady, time dependant state.

6.1.13 This 1D ISIS model comprises of an upper and lower Tame component. The upper Tame includes the Wolverhampton and Olbury Arms of the River Tame which combine upstream of Bescot and extends to Water Orton. The lower Tame extends to the confluence with the River Trent at Alrewas. Therefore the component of relevance to the Proposed Scheme within the study area is the upper Tame.

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[21] http://maps.environment-agency.gov.uk/wiyby/wiybyController?x=357683.0&y=355134.0&scale=1&layerGroups=default&ep=map&textonly=off&lang=_e&topic=floodmap

6.1.14 The 1D/2D ISIS – Tuflow central visualisation mode can model flood extents and flow paths over a floodplain as it is linked to a 2D domain which represents the underlying ground levels.

6.1.15 The model comprises of three component parts (upper, middle and lower). The naming of these is independent of the naming of the SFRM model. The upper model includes the upstream extent of the River Tame catchment as far Newton near Great Barr. The Middle Tame model covers Newton to Nechells and the Lower Tame model, Nechells to Water Orton. The Lower Tame component is of relevance to the Proposed Scheme within the study area.

6.1.16 Both of the Environment Agency models are based on topographical surveyed cross sections of the River Tame channel and the floodplain and include existing flood defences and significant hydraulic structures. The survey data were gathered at various times during the development of these models. No new topographical river surveys have been carried out under this commission.

6.1.17 In order to create a robust river hydraulic model that can accurately simulate the behaviour of the River Tame during flood conditions, the hydrological inputs from the SFRM models have been input to the Central Visualisation model after differences in the model composition have been taken into account. In addition the grid size used to define the resolution of the topographical data used within the model has been reduced from 10m to 6m. This was undertaken to achieve consistency with the River Rea model (detailed in Volume 5: Appendix WR-004-021).

6.1.18 The details of the activities undertaken to produce a robust 'baseline' river hydraulic model are documented in the River Tame modelling report found in Volume 5: Appendix WR-004-019.

6.1.19 At this stage of the design process for the Proposed Scheme, the River Tame baseline modelling outputs shown in this FRA and the accompanying drawings are only relevant to use in the context of the Proposed Scheme. A review was undertaken by the Environment Agency and who were in broad agreement with the approach taken.

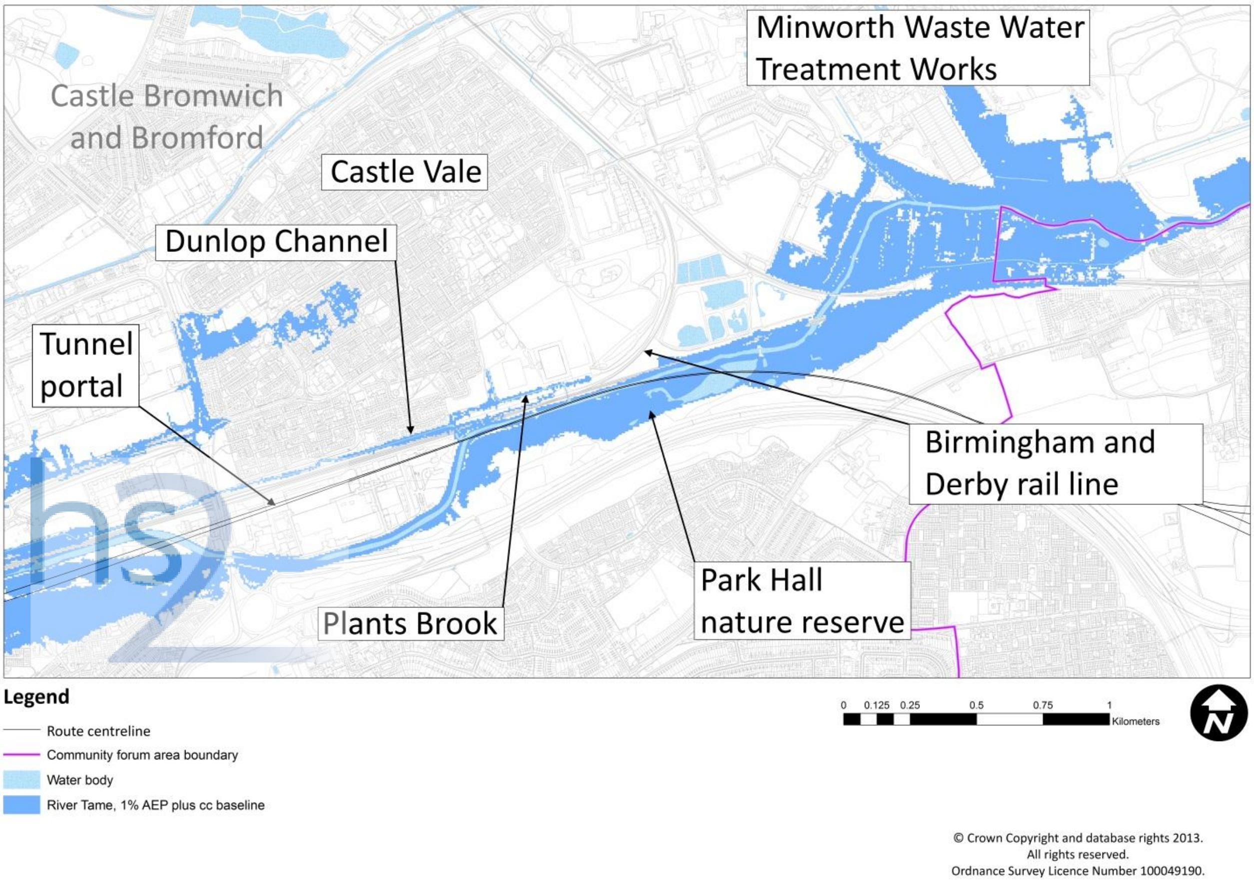
6.1.20 The baseline River Tame model has been used to determine water levels along the river channel and on the floodplain for the following flood events in the pre-development state:

- 50% AEP
- 10% AEP;
- 5% AEP;
- 2% AEP;
- 1% AEP;
- 1% AEP plus CC; and
- 0.1% AEP.

6.1.21 The BCC SFRA does not indicate occurrences of historic flooding along the River Tame in the vicinity of the route.

6.1.22 The results from the baseline model for the 1% AEP plus CC have been mapped across the existing topography. These are shown in the baseline flood maps figures in Volume 5: Map book WR-05-156b-158a with an extract within a key area shown in Figure 2.

Figure 2: Park Hall nature reserve - Flood extent for the 1% AEP plus CC event along the River Tame



6.1.23 The flood model extents show inundation of the same areas as indicated by the existing Environment Agency flood zone mapping. However there are differences in flooding extent in some locations. These are listed below:

- flooding of an existing oil storage depot west of the Fort Shopping Park
- reduced inundation to the west extent of residents south of the River Tame;
- localised inundation of the Fort Parkway and the industrial/commercial areas, north of the A47 Heartlands Parkway including the existing Jaguar Land Rover plant;
- increased inundation of the existing Birmingham and Derby rail line and north of the existing Tame channel in Bromford; and
- reduced inundation in Castle Vale.

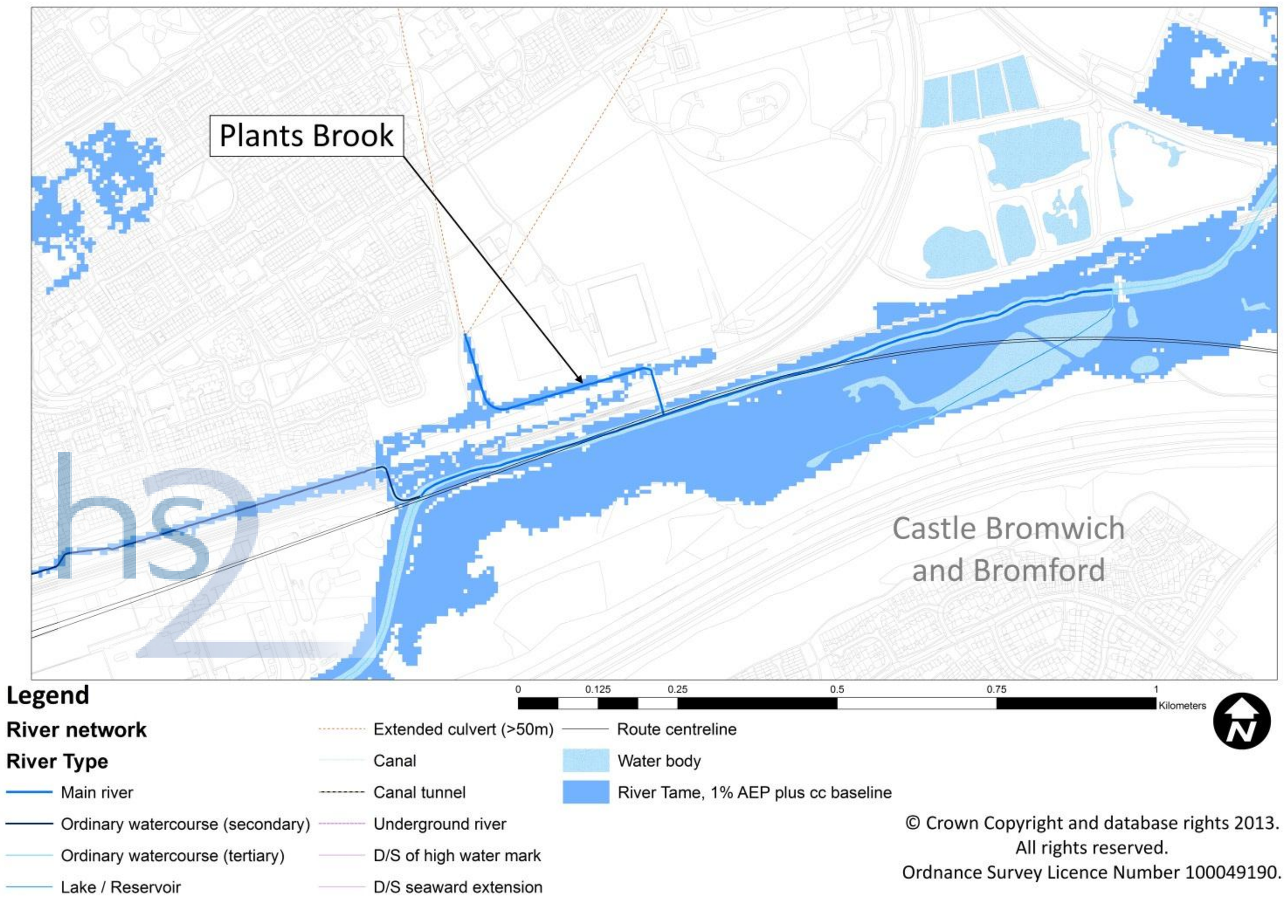
Plants Brook

6.1.24 The Plants Brook is a tributary of the River Tame. It is an Ordinary Watercourse from its headwaters to the A38 Kingsbury Road.

6.1.25 Downstream of Pype Hayes Park it a main river, therefore, regulatory control is with the Environment Agency, although riparian landowners do have a responsibilities to manage the river where it passes through their land and are restricted on what activities they can perform within or adjacent to the river without consent from the Environment Agency.

6.1.26 The entire length of the main river section is culverted through the urbanised area of Castle Vale which is located to the north of the River Tame. The baseline model of the River Tame only accounts for the Plants Brook as a point inflow as it is culverted for such a long length. The modelling results indicate some localised flooding at the interface between the Tame and Plants Brook.

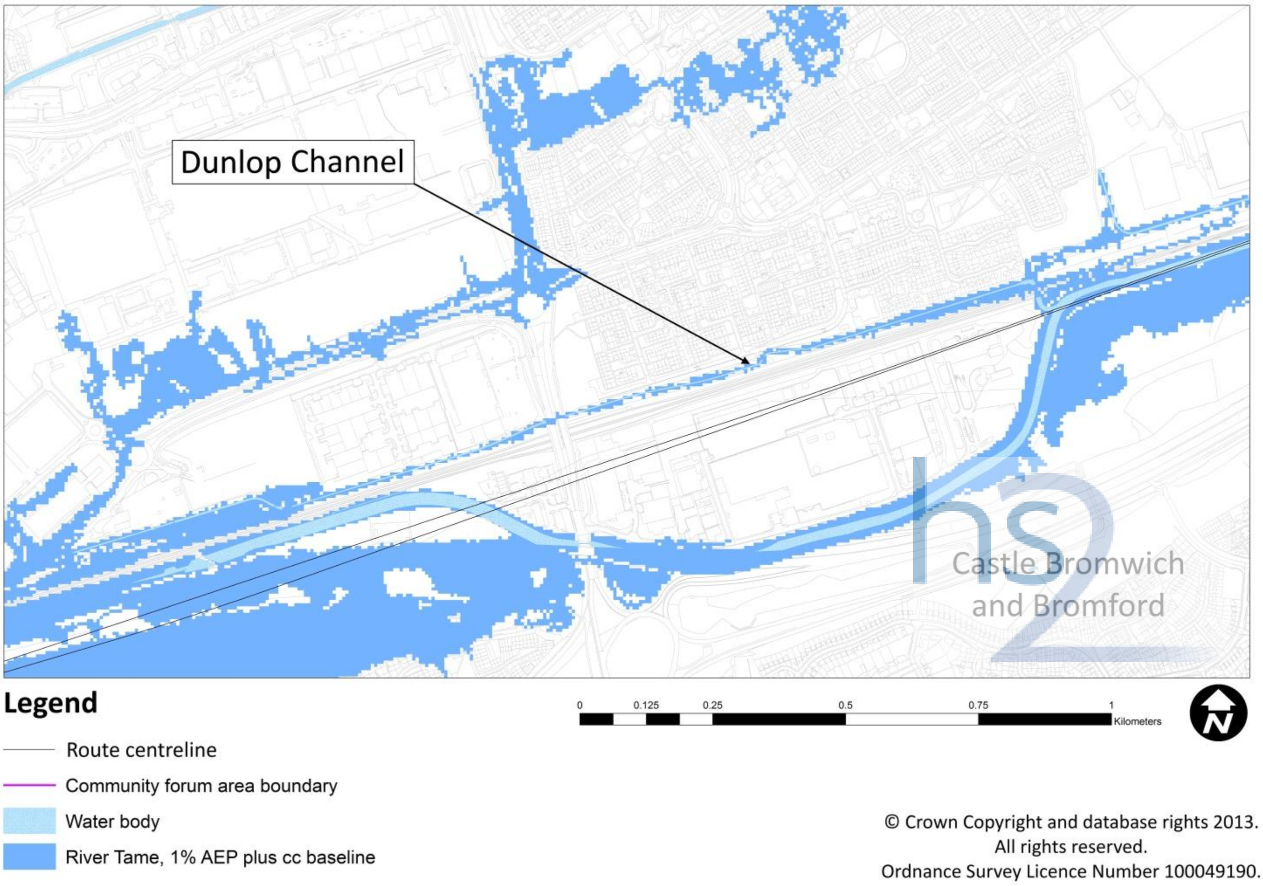
Figure 3: Plants Brook tributary of the River Tame



Dunlop Channel

6.1.27 The Dunlop Channel is a watercourse that runs alongside the River Tame in the Bromford area. It is an ordinary watercourse and therefore regulatory control is with the BCC, although riparian landowners do have a responsibilities to manage the river where it passes through their land and are restricted on what activities they can perform within or adjacent to the river without consent from the BCC. It was originally constructed to accept surface water drainage from the industrial area, which started off as the Dunlop tyre factory. The baseline model of the River Tame includes this feature and the modelling result indicates it accepts water during flood events, but does not indicate it as a source of significant flooding.

Figure 4: Dunlop Channel tributary of the River Tame.



6.2 Surface water and sewerage flood risk

6.2.1 This section is an examination of the existing flood risk posed by rainfall hitting the ground surface. This is often referred to as surface water. In this section it is examined in two ways (i) in terms of the risk posed in the event of failure or exceedance of existing drainage systems, and (ii) in terms of examining the pathways exploited by water flowing over the ground.

Drainage Systems

6.2.2 The route passes through heavily urbanised central Birmingham, which is a predominantly developed area served by traditional urban drainage systems.

6.2.3 Surface water from these areas generally drains to a combined sewer system (meaning surface water and foul water are accepted into the same system) and is discharged to sewage treatment works.

6.2.4 At periods of high intensity rainfall when the capacity of sewers is exceeded, flows are sometimes discharged through Combined Sewer Overflows (CSOs) to local watercourses such as the Tame and its tributaries. CSO's were designed to offer capacity improvements to the system and in some instances they are able to provide storage and so regulate the rate of discharge. However, in some instances the systems are unable to provide any storage and so the flow from the CSO to the watercourse is unattenuated.

6.2.5 There are about 30 drainage area zones covering the whole of the Birmingham area. These drain down various trunk sewers to the Minworth sewage treatment works on the north-eastern side of the city.

6.2.6 The majority of the system is the responsibility of STW. Although within this overall system there are also separate surface water sewers. These tend to be BCC highway drains or privately owned. These take the run-off directly to the local brooks, watercourses or the STW sewerage system.

Route wide within CFA25

6.2.7 The existing sewer catchments affected by the Proposed Scheme are described below.

6.2.8 East of Washwood Heath, large urban areas in the River Tame valley lie below the level of the receiving trunk sewer with foul and combined sewer networks in this area discharging to it from pumping stations.

6.2.9 Districts on the south of the River Tame on higher ground in Castle Bromwich and Hodgehill are served by foul and combined sewer systems which also outfall to this trunk sewer via pumping stations and siphons which traverse the river valley. This includes a combined sewer comprised of four 1200mm diameter sewers. These pass under the River Tame and its floodplain at the location of the proposed tunnel portal.

6.2.10 The flood risk posed by the existing sewerage systems located along the route has been qualitatively assessed. Information from BCC's Level 1 SFRA and the PFRA indicates where historic sewerage flooding has occurred. No historic flooding from sewers is shown along the proposed route in the BCC SFRA plans found in Annex A of this report.

Surface water flow flood risk

6.2.11 The assessment of the existing flood risk posed by existing surface water flow routes has been based on the following:

- an investigation of existing topography using contours generated from LiDAR survey data;
- examining the Environment Agency's surface water flood mapping; and
- documenting any reported instances of flooding from the BCC's SFRA and PFRA.

Route wide within CFA25

6.2.12 Essentially the route follows the valley of the River Tame. Consequently local surface water flow routes are towards the Proposed Scheme.

6.2.13 This means that where the valley of the River Tame is followed, surface water flow is from the north and the south. The general direction of surface water flow is shown in Annex B of this report.

6.2.14 However, the high levels of urbanisation within Birmingham including the extensive road, rail and canal networks mean that the opportunity for water to flow across the valleys is far more limited than suggested on these plans.

6.2.15 The Environment Agency's surface water flood mapping has also been examined and is shown in Volume 5: Map book WR-01-42. These have been compiled by the Environment Agency using a simple ground model to indicate where surface water would be expected to flow or pond during the 0.5% AEP rainfall event. The mapping provides an indication of flooding greater than 0.1m depth and flooding greater than 0.3m deep. This data does have limitations but illustrates areas that may be at risk and where a more detailed study may be required as the design develops.

6.2.16 On the whole, the data set does pick up the significant features that would be expected to be inundated by significant depths of water during rainfall events. These include watercourses and canals as well as the features of interest in this assessment such as low spots in topography. However the low resolution of the mapping and the fact that existing surface water sewerage infrastructure is not considered in the analysis means that a great number of 'low spots' are identified as potential 'at risk locations'. Therefore, a large number of locations across CFA25 are identified with a particularly high frequency of surface water flooding in Bromford and Castle Vale.

6.2.17 Despite this, the data set has been used to identify the following locations along or in close proximity of the route where surface water flow may be a flood risk consideration:

- A4540 Lawley Middleway where it passes under the existing railway bridge; and
- Duddeston Mill Road under the existing rail bridge.

6.2.18 An instance of historic flooding in the Bromford area has been attributed to surface water flow. This is identified in BCC's SFRA. This is not indicated to be in close proximity to the route.

6.3 Groundwater

6.3.1 Groundwater flood risk within the Castle Bromwich and Bromford area has been qualitatively and quantitatively assessed based on hazard identification and evaluation using the conceptual understanding of the ground conditions along the route as informed by geotechnical desk studies and by initial groundwater modelling. The assessment of current groundwater flood risk is based on the presence or otherwise of an aquifer and the relative depth to groundwater level, as well as historical information on the occurrence of groundwater flooding incidents.

Baseline Description

6.3.2 The following sections present details of the ground conditions along the route within CFA25 and a literature review of historical groundwater flooding incidents from the BCC's SFRA.

Geology

6.3.3 The solid and superficial geology of the route corridor is presented below.

Solid Geology

6.3.4 The geological structure of CFA 25 comprises Triassic deposits (Mercia Mudstone Group), forming part of the Knowle Basin, overlain by glacial and alluvial superficial deposits.

6.3.5 At the Lawley Middleway, beyond the extent of CFA25, the route crosses the line of the Birmingham Fault which trends southwest–northeast. This fault exposes the Triassic Sherwood Sandstone Group, Bromsgrove Sandstone formation to the west of the fault.

Superficial Geology

6.3.6 The superficial deposits overlying the solid geology includes the following strata:

- Alluvial deposits;
- River Terrace deposits;
- Glacial deposits; and
- Made ground.

6.3.7 The River Rea Alluvial Deposits, laid down by the Rivers Rea and the Tame since the end of the last (Devensian) glacial period, generally comprise clayey silts, sand and gravel and can be up to 5m thick, typically 3 – 4m. In many places the alluvial material has been disturbed by the construction of mills, flood defences, and urban development, and merges into an extensive spread of Made Ground reflecting human activities.

6.3.8 Along the valley bottom of the River Tame there are a well-developed series of River Terrace Deposits. The younger and more extensive deposit – the First Terrace – was formed during the last glacial period when the Devensian Ice Sheet encroached into the catchment of the River Tame in the Walsall area and is comprised of a sand and gravel layer that is generally 4– 5m thick. This was originally 1–3m above the present day alluvial floodplain, but this relationship is largely obscured by urban development and filling across the valley bottom.

6.3.9 The older Second Terrace (Hams Hall Terrace) occurs as a semi-continuous feature along the lower part of the valley side, particularly on the north side. It generally occurs about 7m – 9m above the present day floodplain, but the elevation is variable, and there may be more than one age of material. It comprises a clayey sand and gravel, generally 2m – 4m thick, which is extensively cryoturbated in places.

6.3.10 The superficial glacial deposits form a discontinuous covering to the Triassic deposits across the upper parts of the Rivers Rea and Tame valley sides. These deposits probably reflect several phases of glaciation between about 400,000 and 200,000 years ago. Due to erosion by the Rivers Rea and Tame after the last glacial phase, the cover of glacial material is now discontinuous. They also occur within linear hollows eroded into the Triassic strata, by subglacial melt water during a previous glacial period.

6.3.11 Most of the glacial deposits present are sands and gravels formed during the decay of the glacial phases. However within the subglacial channel, a more diverse sequence of glaciolacustrine silts and fluvio-glacial sands and gravel occur, and within this sequence interglacial deposits are present in places, indicative of possibly more than one glacial phase.

6.3.12 Significant spreads of Made Ground affect CFA 25, relating to past human activities. Much of this Made Ground has been placed across the valley bottoms of the Rivers Tame and Rea to provide development platforms above flood levels for industrial land use, and as embankments for main line railways and extensive railway sidings. Some of this Made Ground is a consequence of the long and intensive industrial land use of the area.

Hydrogeology

6.3.13 The strata have been classified using the Environment Agency aquifer classification framework[22] which is consistent with EU Water Framework Directive (2000)[23]. The aquifer designations for each stratum are summarised in Table 3.

Table 3: Aquifer designations for geological units in CFA25

Geological Unit	Aquifer Designation
Alluvium	Secondary A
River Terrace Deposits	Secondary A
Glaciofluvial Deposits	Secondary A
Mercia Mudstone	Secondary B

6.3.14 The Aquifer Designation is as follows:

- Secondary A aquifers are considered to consist of variable permeability layers capable of supporting water supplies at a local scale; and
- Secondary B aquifers are predominantly of lower permeability and may locally store groundwater due to localised features such as thin fissures, thin permeable horizons and weathering.

6.3.15 No Groundwater Source Protection Zones (SPZ) are located along or within 500m of the route within CFA25.

Historical Occurrence of Groundwater Flooding

6.3.16 Information on groundwater flood risk was obtained from BCC's Level 1 SFRA which identified no historic groundwater flooding within 1km of the route within CFA25.

[22] Environment Agency, (2013). *Aquifer Classification Framework* [online], [Accessed 05-02-2013]. Available from: http://www.environment-agency.gov.uk/homeandleisure/117020.aspx

[23] *Directive 2000/60/EC of the European Parliament and of the Council establishing a framework for the Community action in the field of water policy*, European Council

Current groundwater flood risk

6.3.17 Within CFA25 the route is underlain by generally impermeable (except for weathered top zone and some sand bands) Mercia Mudstone with overlying predominantly free draining sand and gravel superficial deposits such as the River Terrace deposits and Glaciofluvial deposits. These superficial deposits are designated Secondary A aquifers and would expect relatively shallow <5m depths groundwater along the valleys.

6.4 Artificial sources/infrastructure failure

6.4.1 Artificial sources of flood risk describe a mechanism whereby flooding would be the cause of failure of infrastructure in place to impound (reservoir), retain (dam) or convey water (water pipeline).

6.4.2 CFA25 flooding is a possibility from the failure of the following infrastructure:

- sewerage systems (detailed in Section 6.2);
- water supply pipe networks (detailed herein); and
- reservoir failure (detailed herein).

Water supply network

6.4.3 Water mains and water distribution infrastructure are a potential source of flood risk in the event of a failure. This section identifies significant water mains within the network and their position relative to the Proposed Scheme for the baseline condition.

6.4.4 Significance of a water main is based on diameter and pressure. It is assumed that the majority of small diameter pipes within the network are of low risk as the rate at which water escapes will be low. Where the risk is not considered to be low the utility is presented in Figure 5.

Figure 5: Castle Bromwich water mains

6.4.5 An assessment of how existing water supply infrastructure interacts with the Proposed Scheme has been undertaken.

Reservoir failure

6.4.6 The probability of flooding occurring from the failure of a reservoir or large water body created by impoundment of water, by a dam or other retaining structure is extremely low. The Environment Agency's website reports that there has been no loss of life due to reservoir failure in the UK since 1925. All large water bodies across the UK have to be maintained and monitored to a very high standard under the Reservoir Act 1975[24]. This requires regular inspection of any water body designated a reservoir by a nominated engineer. However if a reservoir does fail the impact is likely to be severe and far reaching. It is a requirement of NPPF and The Flood and Water Management Act 2010[25] to evaluate the implications of reservoir failure on all proposed development even if the likelihood is very low. The Flood and Water Management Act 2010 proposes to change the capacity threshold at which reservoirs are regulated from 25,000m^3 to 10,000m^3. Secondary legislation which has yet to be enacted is required to enforce this change.

[24] *Reservoir Safety Act*, (1975), London, Her Majesty's Stationary Office

[25] *The Flood and Water Management Act*, (2010), London, Her Majesty's Stationary Office

6.4.7 To that end the Environment Agency's Reservoir Inundation mapping for the Birmingham area has been compared to the Proposed Scheme. It should be noted that this only accounts for large raised reservoirs (those in excess of 25,000m^3).

6.4.8 This indicates that in the event of a catastrophic failure of the reservoirs in the Tame catchment, the flood waters would flow down the river channels and extend out across the floodplain of the river system.

6.4.9 There are a number of water bodies identified on the Environment Agency Reservoir Inundation maps located within Sutton Park that would have the potential to inundate the Tame valley in the vicinity of the Proposed Scheme. These drain into the Plants Brook. The flooding extents indicate that water would be attenuated within the Plants Brook valley upstream of the A38 Kingsbury Road. These are shown in Annex A.

6.4.10 The Environment Agency Reservoir Inundation mapping has been compared to the river flood extents for the 0.1% AEP event. In most areas the extent of inundation would be approximately equivalent to this flood event. However the Environment Agency data provided does not indicate flood depths, flow velocities or the time taken for onset of flooding after a breach takes place.

6.4.11 It should be noted there are other artificial water bodies identified on BCC's water feature maps located within the Tame catchment. Due to their size (less than 25,000m^3) they will have not been subject to the reservoir inundation analysis.

6.5 Summary of baseline flood risk

Table 4: Summary of baseline flood risk for all sources of flooding in CFA25

Source of flooding	Location of flooding source	Flood risk category	Elements at risk	Assessment of risk
Watercourse	River Tame (including tributaries Plants Brook and Dunlop Channel)	Very High FZ3b	Viaduct and embankment through Park Hall nature reserve	Rail level >1m above 0.1% AEP water level
	River Tame	Medium Flood Zone 2	Bromford tunnel east portal	Flood protection walls implemented to safeguard portal up to the 0.1% AEP water level
		Very high FZ3b	Bromford tunnel	Proposed Scheme in tunnel - No Risk
		High	Network Rail Track	Culverts under Network Rail Track sized to match existing and maintain current flood conditions

Source of flooding	Location of flooding source	Flood risk category	Elements at risk	Assessment of risk
	Dunlop Channel	High	Proposed Scheme embankment and Network Rail	Rail level >1.0m above 0.1% AEP water level Culvert sized to match existing upstream Network Rail culverts in order to maintain existing flow conditions and maintain existing flood risk.
		High	Bromford tunnel east portal	Flood walls to be provided to protect against 0.1% AEP river flood event.
		High	Residential housing adjacent to Dunlop Channel	Culvert sized to match existing upstream Network Rail culverts in order to maintain existing flow conditions and maintain existing flood risk.
	Plants Brook	High	Residential housing adjacent to Plants Brook	Culvert sized to match existing upstream Network Rail culverts in order to maintain existing flow conditions and maintain existing flood risk.
Artificial sources	Water bodies contributing to the River Tame including, reservoir at Perry Park, Aston Reservoir and Erdington Reservoir	Low - Within inundation mapping / pathway exists	Bromford tunnel	Proposed Scheme in tunnel - No Risk
			Bromford tunnel eastern portal	Flood protection walls.
			Viaduct and embankment through Park Hall nature reserve	Rail level >1m above flood level
Surface Water	Proposed Scheme track drainage	Low	River Tame	Additional run-off from track drainage to be attenuated to pre-development greenfield/ brownfield run-off rates within balancing ponds prior to discharge to River Tame.

Source of flooding	Location of flooding source	Flood risk category	Elements at risk	Assessment of risk
	Bromford tunnel east portal pumping station	Low	River Tame	Outflow from pumping station to be attenuated to pre-development run-off rates within balancing ponds prior to discharge to River Tame. Pump Station outfall ditch and pond provided to reduce flow surges from pumps.
Groundwater	Superficial deposits in Tame valley Castle Bromwich (Bromford tunnel east portal and approach)	Medium - High groundwater in superficial deposits"	Bromford tunnel approach and portal	No historical incidents of groundwater flooding. Tunnel approach barrier to groundwater flow.

7 Flood risk management measures

7.1.1 The purpose of this FRA is to demonstrate that within CFA25, the Proposed Scheme will not increase flood risk to any third party land owners and that the Proposed Scheme can be implemented without putting proposed infrastructure at risk of flooding.

7.1.2 To do this a number of physical mitigation measures have had to be included in the design to either safeguard adjacent land users or the Proposed Scheme and associated infrastructure. These physical measures are described below

7.1.3 The portals to Bromford tunnel are located in (west) Washwood Heath Depot (CFA 26) and (east) in an industrial area to the south of Jaguar Land Rover.

7.1.4 The eastern portal for the Bromford tunnel is located outside of the area predicted by river hydraulic modelling to be inundated during the 0.1% AEP flood event. However, due to the significant impact that would be caused if the portal were to become inundated by River Tame it has been decided to incorporate flood management measures.

7.1.5 Accordingly a flood defence structure will be provided to protect the Bromford Tunnel east portal.

7.1.6 River hydraulic analysis includes the incorporation of a flood defence wall at the eastern portal approach (in the vicinity of Dunlop Channel) and confirms no increase flood risk outside the Parkhall nature reserve up to the 1% plus CC.

7.1.7 The western portal of Bromford tunnel is located within CFA 26 and so measures associated with this feature are addressed in the flood risk assessment for CFA26 (see Volume 5: Appendix WR-003-026).

7.1.8 Provision has been made to capture and dispose of surface water entering the tunnel portal. This will require the incorporation of a pumped system designed to enable transfer of the water out of the tunnel. This system is designed to manage surface water flows up to the 0.1% AEP.

7.1.9 The tunnel portals include pile walls extending through the superficial deposits into the underlying Mercia Mudstone, initial numerical groundwater modelling has identified the risk of a long term increase in groundwater levels which may cause localised shallow groundwater conditions or groundwater flooding. Suitable water-proofing will be provided to the structure to prevent water inundation and groundwater drainage will be provided to mitigate impacts of the structure on groundwater flow and level.

7.1.10 Realigning the River Tame within Park Hall nature reserve will disrupt the existing interaction between the River Tame channel and its floodplain within this area. Consequently it will be necessary to provide replacement floodplain storage with sizing determined using the hydraulic model (see Volume 5: Appendix WR-004-019). This will be provided by re-grading Park Hall nature reserve or alternative mitigations that may be developed at later stages of the design.

7.1.11 Surface water management across CFA25 will be provided to collect and convey surface water away from the Proposed Scheme and adjacent third party land vulnerable to flooding (water sensitive properties and infrastructure) up to the 0.1% AEP rainfall event. To achieve this on site flows will be strictly regulated by implementing attenuation storage and off site receptors will be considered in the event of rainfall events that exceed the design standard.

8 Post-development flood risk assessment

8.1 River flood risk

River Tame

8.1.2 The Proposed Scheme has been incorporated into the refined river hydraulic model of the River Tame to produce a post development model. The full range of flood events have been simulated within this model to determine the impact caused by the proposed scheme on the performance of the River Tame during extreme flood conditions.

8.1.3 At this stage of the design process the River Tame baseline modelling outputs shown in this FRA and the accompanying drawings are only relevant to use in the context of this design stage.

8.1.4 The design elements that have a flood risk consideration associated with the Tame or its tributaries are:

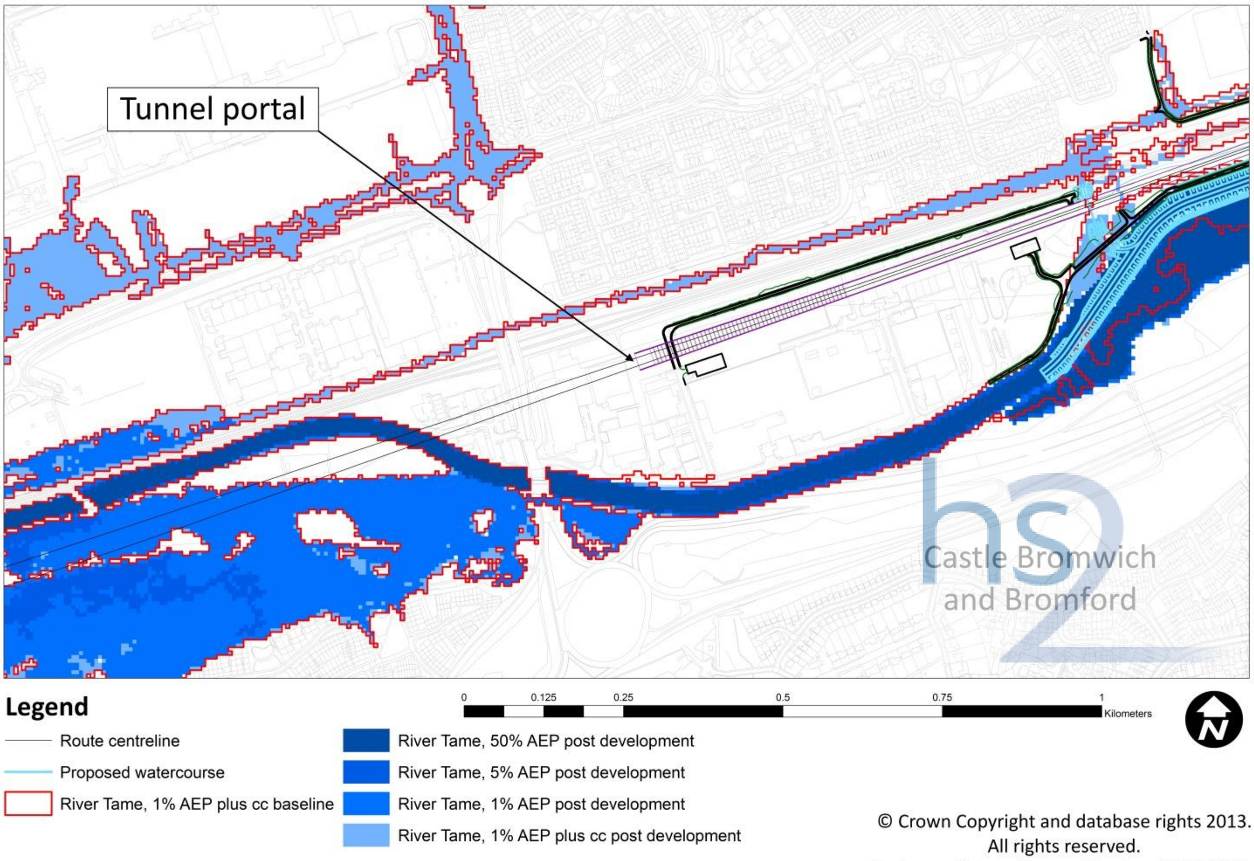
- Bromford tunnel east portal;
- Dunlop Channel inflow;
- Plants Brook inflow; and
- works at Park Hall nature reserve including diversion of the River Tame and re-grading of the floodplain.

8.1.5 The river flood risk considerations associated with these design elements are examined in the following sections.

Bromford tunnel east portal

8.1.6 The Bromford tunnel east portal will be protected against inundation up to and including the 0.1% AEP flood extent. The tunnel portal location and associated infrastructure does not change the flooding extent generated during a 1% AEP plus CC flood event in this area. This is indicated in Figure 6.

Figure 6: Flood extent for the 1% AEP plus CC event at the location of the east portal for baseline and post development model.



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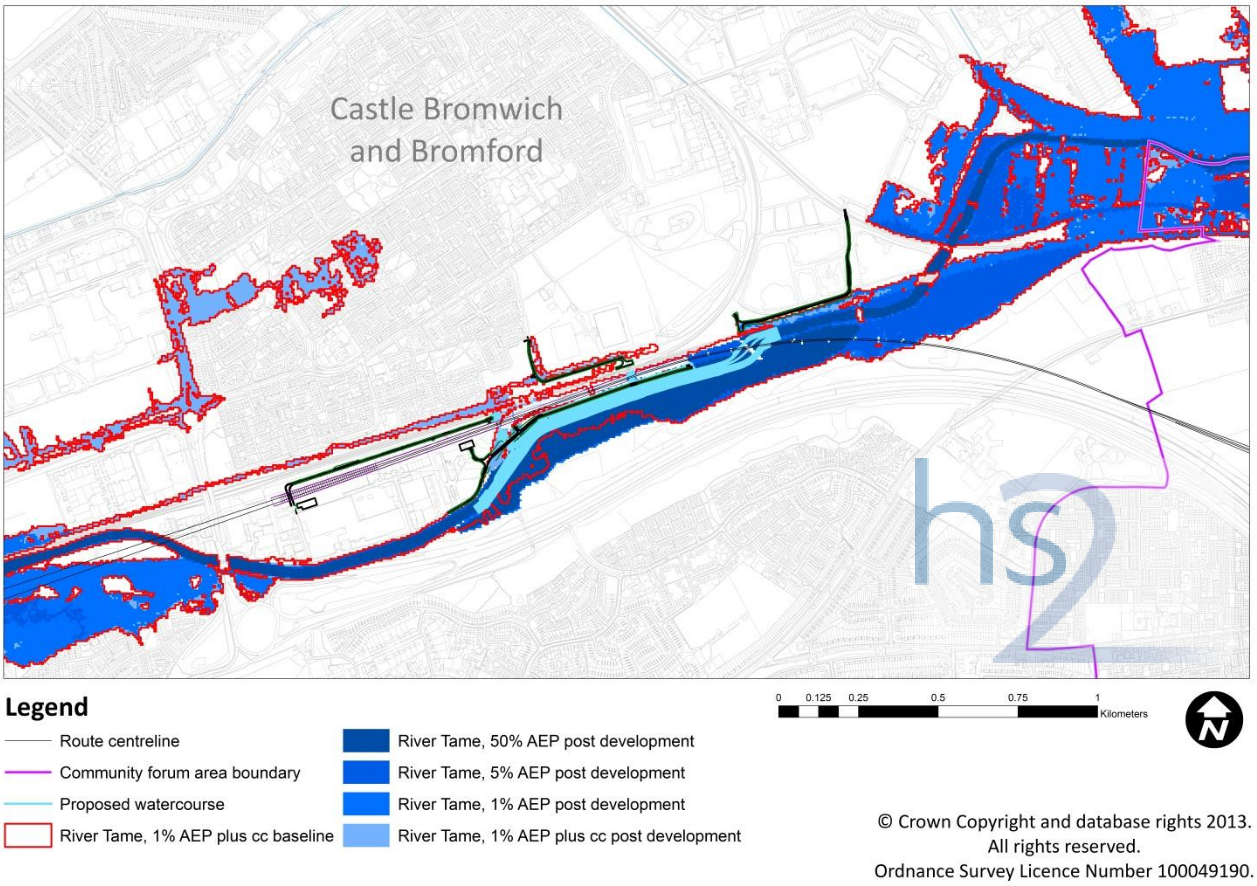
Park Hall Nature Reserve

8.1.7 The route runs on embankment along the alignment of the existing River Tame parallel to the nature reserve for approximately 600m before crossing the nature reserve on a viaduct structure. There is therefore a requirement to divert the River Tame from its existing alignment to facilitate the construction of the Proposed Scheme.

8.1.8 The proposed diversion runs in a straight channel parallel to the Proposed Scheme within Park Hall. The route will be on embankment on the northern side of the Park Hall nature reserve. The impacts on flood extent generated by these proposals are indicated in Figure 7. The channel will be designed with due consideration of the requirements of the Water Framework Directive.

8.1.9 It is proposed to re-grade the local topography in such a way that the replacement floodplain storage required is created within Park Hall nature reserve. Consequently Figure 7 indicates an increased area of flooding on the western side of the nature reserve. Flood levels in Parkhall Nature Reserve are increased by up to 30mm for the 1% AEP plus CC event in a water compatible area. This local change in topography maintains the hydrological and hydraulic regime up and downstream of the nature reserve and as such no significant effects on flood risk to third parties (such as downstream property, highways and existing rail infrastructure) have been identified within this assessment. Alternative mitigations will be considered at later stages of the design.

Figure 7: Flood extent for the 1% AEP plus CC event at Park Hall nature reserve for post development model.



Dunlop Channel and Plants Brook

8.1.10 As the River Tame is being diverted through Park Hall nature reserve the existing connections between the Dunlop Channel and the River Tame and the Plants Brook and the River Tame are being disrupted. Alternative connections are provided into the diverted River Tame to match existing structures.

8.2 Surface water and sewerage flood risk

8.2.1 This section describes how surface waters generated by the Proposed Scheme and associated infrastructure (such as highway diversions, Washwood Heath Depot and Curzon Street Station) will be managed to ensure the Proposed Scheme will not be at risk of inundation during all flood events up to the 0.1% AEP.

8.2.2 In addition a description is given of the risk posed by surface waters to third party land taking account of where the route or associated infrastructure disrupts existing infrastructure and drainage paths.

Proposed surface water infrastructure/sewerage

Route wide within CFA25

8.2.3 At this preliminary design stage the surface water management strategy for railway infrastructure has been based on a conveyance system with sufficient capacity to collect and convey surface water to attenuation areas for all events up to the 0.1% AEP rainfall event. In this way the Proposed Scheme will be protected.

8.2.4 Ponds are the preferred method of flow attenuation due to the linear nature of the project and the requirement to control run-off at managed discharge points (design drawings are shown in Volume 2: Map book CT-06).

8.2.5 Based on the available information at this time and due to the likely presence of contaminated ground combined with high groundwater levels it is highly unlikely that infiltration techniques will be a viable method of surface water disposal in this section of the route. Site investigations will be undertaken as the design progresses.

8.2.6 In CFA25 the Proposed Scheme's railway drainage systems discharge to watercourses. There are no surface water outfalls anticipated to public sewers.

8.2.7 The flow attenuation areas have been sized to balance the 1% AEP plus CC rainfall event, assuming a discharge rate that matches the existing conditions with a 20% reduction in accordance with BCC requirements. This is a local requirement to manage capacity issues within the current system. Where there are undeveloped areas the discharge is restricted to greenfield rates. For surface water management the climate change allowance has been taken as a 30% increase in rainfall intensity.

8.2.8 Discharge rates from each catchment have been calculated based on the method described in the Institute of Hydrology Report 124 (1993)[26], adopting appropriate urban factors for developed areas. This method has been employed in the way described in Interim Code of Practice for Sustainable Drainage Systems.

8.2.9 The attenuation storage calculations for the Proposed Scheme have assumed a conservative run-off coefficient, (i.e. the majority of the rainfall landing on the ground will enter the drainage system).

8.2.10 Where the adjacent land falls towards the railway (or there are existing urban drainage systems that may divert flows towards the railway), a cut off drainage system and threshold protection measures are provided to intercept the flows from external catchments and divert them to the nearest crossing point of the route, usually a bridge or culvert conveying a watercourse under the Proposed Scheme.

8.2.11 At the Bromford tunnel east portal sections of the railway are too low to outfall by gravity and require pumping stations to lift surface water run-off to ground level prior to being discharged to watercourses.

[26] Marshall, D.W.C. and Bayliss, A.C., (1993), *Flood Estimation for Small Catchments report number 124*, Natural Environment Research Council.

8.2.12 'Emergency' or 'part time' surface pumping stations will also be required at sections of railway. The system will drain by gravity most of the time, but where flood walls are installed and the rail levels are less than 1m above the 0.1% AEP river water levels, pumping will be required during periods when river levels are high. This will require the installation of non-return valves on the outfall pipes so that flood water does not backflow in to the railway drainage during these river events.

8.2.13 The railway drainage catchments are listed in Table 5 and shown in drawings included in Annex B of this report.

Table 5: Railway Drainage Catchments and Outfalls.

Linear km of route drained	Description	Receiving watercourse	Brownfield peak discharge rate Q100/A (l/s/ha)*	Post-development peak discharge rate Q100/A (l/s/ha)**	Outfall Number
0.36	Gravity	River Tame	3.9 - 22.7	3.1 - 18.2	O-1665
0.55	Gravity	Plants Brook	3.3 - 22.7	2.6 - 18.2	O-1667
0.83	Pumped (tunnel portal)	River Tame (Dunlop Channel)	3.3 - 22.7	2.6 - 18.2	O-1670

Notes: *Q100/A is the 1%AEP peak discharge rate of run-off per unit area, derived from QBAR estimation for urban catchments with Urban Growth Factor applied (ICoP and IoH 124 cl 7.3). **Allowable post development discharge rate is the brownfield Q100/A with 20% betterment.

Existing surface water infrastructure/sewerage

Route wide within CFA25

8.2.14 The Proposed Scheme will require the diversion or replacement of a number of existing public highways. The associated highway drainage systems will require reconfiguration or replacement. However in this section no completely new highway surface water outfalls to public sewers or other water bodies are anticipated.

8.2.15 A significant combined sewer comprising four 1200mm pipes passes through the route at the Bromford tunnel east portal. This feature will have to be protected or diverted in advance of commencing tunnelling works.

Surface water flow flood risk

8.2.16 The design seeks to replicate existing catchment distributions and minimise alterations to surface water flow paths from their existing routes. Where this is not possible, a safe and secure route for drainage systems and surface water flows has been identified such that there is no increased flood risk to properties or businesses.

8.2.17 Where the route is above ground it runs parallel to the Rivers Tame and Rea and is predominantly located either within or on the margins of the floodplains of these rivers. It also runs alongside the existing railway, which in itself is a continuous linear feature that forms a barrier to drainage paths and drainage systems.

8.2.18 Key locations are analysed in the Sections below.

Bromford tunnel east portal

8.2.19 Between the proposed Tame viaduct, through Park Hall nature reserve and the Bromford tunnel east portal, the surface water catchments on the northern side will be intercepted by the existing railway embankment and are directed towards the watercourses crossing under the railway; namely the Plants Brook and the Dunlop Channel.

8.2.20 After construction of the Proposed Scheme, alternative connections for the Dunlop Channel and Plants Brook under the railway embankment are provided into the diverted River Tame. Therefore there are no significant alterations to existing surface water flow paths.

8.2.21 The catchments on the south side of the Proposed Scheme will continue to outfall to the River Tame and are unaffected.

8.3 Groundwater

8.3.1 It is assumed that the principal mechanism by which Proposed Scheme will increase groundwater flood risk, is where impermeable structures (e.g. lined tunnels and pile walls) act as a barrier to groundwater flow and have the potential to cause a rise in groundwater level with mounding in the vicinity of these structures. Other changes to the groundwater environment, such as through drained cuttings, are not assumed to increase the groundwater flood risk as the drainage element is assessed as part of the Proposed Scheme's drainage system.

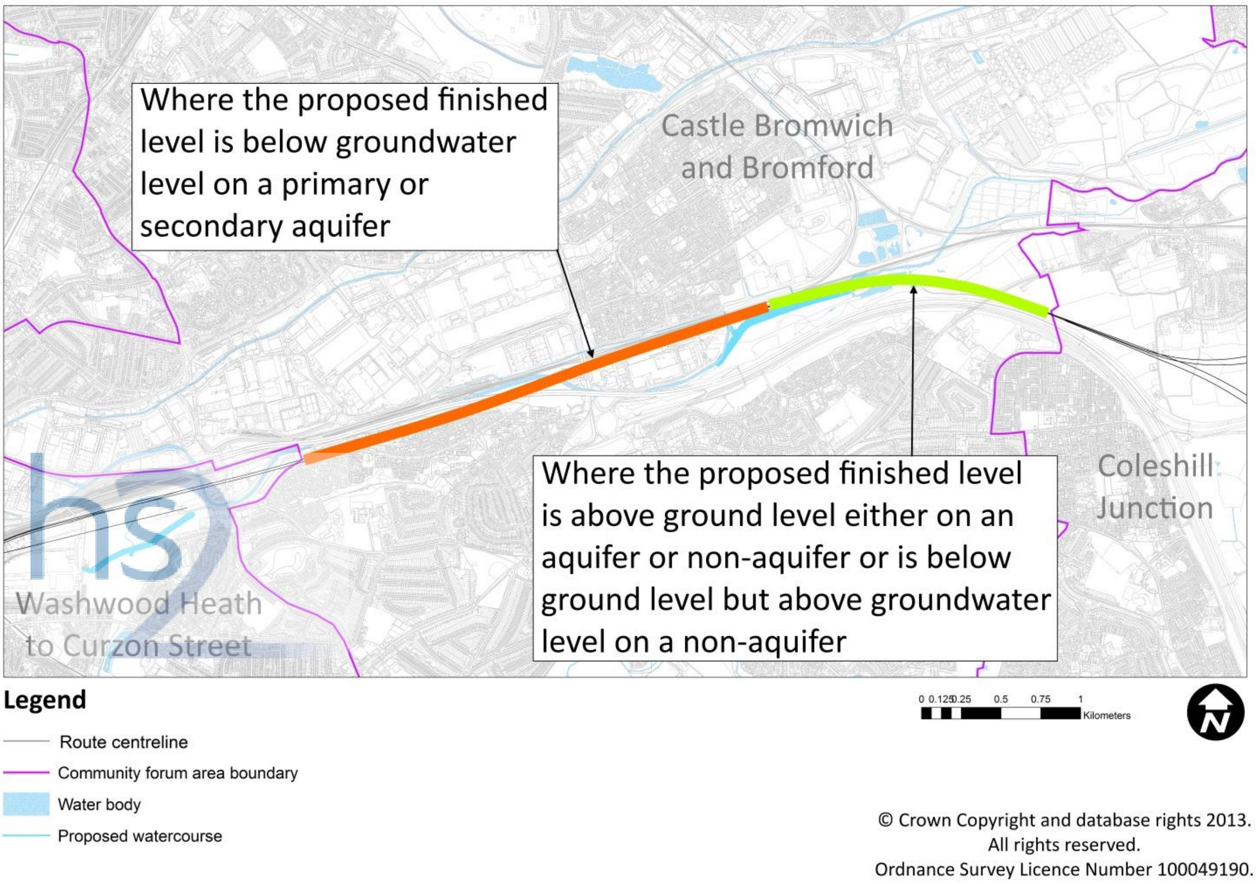
8.3.2 To assess the possible changes to groundwater levels and flows, and the associated change in groundwater flood risk, a high level assessment (see Volume 5: Appendix WR-004-020 for the findings of the initial groundwater modelling) of the groundwater conditions along the route has been undertaken to understand where the Proposed Scheme is likely to interact with groundwater (i.e. it is on an aquifer and within the proximity of groundwater levels). These areas have the potential to increase relative groundwater flood risk although further assessment of the proposed design and structures is made to confirm whether a change in groundwater flood risk is likely. Further field data collection and analytical or numerical modelling is then recommended to quantify this change. Table 6 shows the criteria used to identify areas where changes to the level of groundwater flood risk along the route corridor may occur from the introduction of the Proposed Scheme.

Table 6: Criteria to identify areas where changes to groundwater flood risk may occur.

Low	Where the proposed finished level is above ground level either on an aquifer or non-aquifer or is below ground level but above groundwater level on a non-aquifer
Medium	Where the proposed finished level is below ground level but above groundwater level on a primary or secondary aquifer
High	Where the proposed finished level is below groundwater level on a primary or secondary aquifer

8.3.3 Information presented in Table 7, and summarised in Figure 8, illustrate the areas within CFA25 where there is greater potential for changes to groundwater flood risk post development to the Proposed Scheme and third parties.

Figure 8: Areas of greater potential for changes to groundwater flood risk within CFA25.



8.3.4 The main section of the route where there is an increase in groundwater flood risk is between Chester Road and just north of Langley Hill Wood where the proposed twin bore tunnel (Bromford tunnel) and portal passes through the Secondary aquifer superficial deposits. In this area the tunnel and portal have the potential to act as a local barrier to shallow groundwater flow which may cause mounding and a rise in groundwater levels (the proposed Bromford tunnel is a 7m bored in ~6m of superficial aquifer). An initial numerical groundwater model has been developed to assess the potential change in local groundwater levels, and to inform design mitigation measures to control groundwater levels to an acceptable level.

8.3.5 The groundwater model indicates that without mitigation measures there is likely to be a long term increase in groundwater level within the superficial deposits in the area of the Bromford tunnel east portal, where the pile walls will act as a barrier to groundwater flow, potentially causing localised shallow groundwater conditions or groundwater flooding. Water-proofing of the structure will be provided to the structure to prevent water inundation and sub-surface drainage will be provided to mitigate the impacts due to the structure on surrounding groundwater flows and levels.

Table 7: Summary of the conditions along the route corridor and areas where the groundwater flood risk may change

Approximate grid Reference	Existing ground level (mOD)	Proposed level (mOD)	Assumed groundwater level (mOD)	Aquifer classification (Superficial)	Aquifer classification (Solid Geology)	Superficial Geology	Solid Geology (approximately depth, m) at reference borehole	Title	Reference borehole	Distance to referenced borehole (m)	Assumed depth to groundwater level (m) at reference borehole	Assumed ground level (mOD) at reference borehole
SP1629 9078	82.7	87.9	81.7	Secondary A and undifferentiated	Secondary B	Alluvium over Head deposits	Mercia Mudstone (5)	River Tame viaduct	SP19SE57	100	1	78
SP1518 9077	77.5	85.1	76.5	Secondary A	Secondary B	Made Ground, Alluvium (variable clay/gravel)	Mercia Mudstone (5)	Plants Brook underbridge	Geological map only		1	77
SP1476 9062	82 – 83	83 – 63	80	Secondary A	Secondary B	Made Ground, Alluvium (variable clay/gravel)	Mercia Mudstone (8)	Bromford tunnel east portal (Retained Cut)	various	n/a	2 – 3	n/a
SP1405 9037	83 – 90	57	80	Secondary A	Secondary B	Made Ground, Alluvium (variable clay/gravel)	Mercia Mudstone (8)	Bromford tunnel (bored tunnel)	various	n/a	2 - 3	n/a

8.4 Artificial sources/infrastructure failure

Water supply network

8.4.2 Overland flow has been adopted as a term in this section to distinguish it from surface water flooding i.e. where the capacity of the drainage system is exceeded. Overland flow in this section refers to flow over the surface which is caused by infrastructure failure.

8.4.3 Assets are mapped and where appropriate the potential overland flow paths inspected by interrogation of topographic data. The extent of overland flow from a burst water main will depend on the discharge rate which is influenced by a number of factors including water main diameter, pressure, depth and upstream water source. Given the limited data available and complexity in accurately assessing overland flow routes, this FRA is limited to identification of potential flow paths only.

8.4.4 Where existing or diverted water mains and water distribution infrastructure have been judged to offer a potential source of flood risk from an upstream catchment an assessment of potential surface water flow routes have been made of the risk associated with this source.

8.4.5 No diversion is proposed to Bromford, Castle Bromwich or Park Hall Wood water mains and therefore no change in risk is envisaged from the water supply network.

Reservoirs/large water bodies

8.4.6 This section describes the potential risk posed in the event of a catastrophic failure of the reservoirs and other large water bodies in the vicinity of the Proposed Scheme. It is important to have awareness about the impact of failure of reservoirs and large water bodies; although the risk is low, the impact can be high.

8.4.7 There is no intention to impact on the structural integrity of the reservoirs/large water bodies at source and hence will not increase the risk of this occurring.

8.4.8 The Environment Agency's reservoir inundation mapping indicates potential flow paths for large quantities of water to reach the Proposed Scheme in the event of reservoir breach, which could have a significant impact on features such as the Bromford tunnel. The baseline reservoir inundation is similar in extent to the 0.1%AEP river flood extents. The route is protected up to the 0.1% AEP for river and surface water flooding and therefore the scheme will be protected against flooding due to the failure of these reservoirs subject to the correct implementation of all mitigation measures.

8.5 Summary of potential impacts on flood risk

8.5.1 Reference should be made to the flood maps provided in Volume 5: Map book WR-05. A summary of main receptors is provided in Table 8.

Table 8: Summary of potential flood risk impacts in CFA

Receptor	Vulnerability Classification (from NPPF)	Pathway	Impacts
Proposed Scheme: General		Watercourse	Realignment of River Tame required through Park Hall nature reserve. To maintain the flood risk downstream replacement floodplain storage within the nature reserve or alternative mitigation measures will be provided. This extends the area of inundation within the nature reserve. This can be done without increasing flood risk to people or property. The route is located within a tunnel through the Bromford area this removes any impact on the River Tame for a significant proportion of this community forum area (CFA). Flood walls will be provided to protect against 0.1% AEP river flood event.
		Surface water and drainage systems	Flood walls to be provided to protect Proposed Scheme from surface water flow. Surface Water drainage network designed to maintain 0.1% AEP water level >1.0m below rail level.
		Artificial Bodies	Flood waters released by the failure of the artificial water bodies identified in CFA25 would flow along the River Tame. Therefore, due to the replacement floodplain storage in Park Hall nature reserve, this area will flood to a greater degree if there was a failure within the Tame catchment.
Park Hall nature reserve	Water compatible	Watercourse	River realignment work required for implementation of the Proposed Scheme requires local replacement floodplain storage within Park Hall nature reserve. This will increase the extent of the floodplain in this area while safeguarding other areas against any increase.
Minworth Sewage Treatment Works	Less vulnerable	Watercourse	By ensuring replacement floodplain storage is supplied in Park Hall nature reserve there will not be an increase in downstream flood risk. Consequently the risk posed to Minworth STW will be as existing
Proposed Scheme: Bromford tunnel east portal and approach	Essential infrastructure	Watercourses	The portal will be protected against flood events up to the 0.1% AEP.
	Essential infrastructure	Groundwater - high	Tunnel approach and portal within the superficial deposits, modest (<1m) change in groundwater level with mitigation provided to the tunnel (water-proofing) and surrounding areas by groundwater drainage systems.
Tameside Drive industrial area	Less vulnerable	Watercourse	The scheme will not increase flood risk at this location.
Residential areas of Bromford	More vulnerable	Watercourse	The scheme will not change the increase flood risk at this location.
Birmingham and Derby Line	Essential infrastructure	Watercourse	No change to flood risk. Culverts beneath Proposed Scheme which convey Plants Brook and Dunlop Channel will be sized based on the

Receptor	Vulnerability Classification (from NPPF)	Pathway	Impacts
			existing structures.
Residential housing adjacent to Dunlop Channel and Plants Brook	More vulnerable	River & surface flow	The scheme will not change the flood risk at this location.
M6 Motorway	Essential infrastructure	Watercourse	The scheme will not change the flood risk at this location.

9 Conclusions

9.1.1 This FRA accounts for the flood risk considerations caused by construction of the Proposed Scheme within CFA25 - both to the Proposed Scheme and to third parties.

9.1.2 River hydraulic models of the River Tame have been obtained from the Environment Agency. These have been updated and validated and used to determine the existing baseline flood risk posed by these watercourses for a range of return period flood events as well as flood levels up to and including the 0.1% AEP flood. This has resulted in the production of flood maps for the 5% AEP and 1% AEP +CC events which shown in WR-05 and WR-06 within the Volume 5 Map Book for Water Resources.

9.1.3 The Proposed Scheme has been incorporated into the existing baseline models in order for the impact of the proposals on flood risk to be determined.

9.1.4 The Proposed Scheme will be designed to be resilient up to and including the 0.1% AEP storm event. This will be achieved by either setting the rail level at 1m above the 0.1% AEP flood level or by protecting the route using flood defence structures set at a level that is equivalent to 300mm above the 0.1% return AEP flood level.

9.1.5 A diversion of the River Tame is necessary through the Park Hall nature reserve. The channel design, replacement floodplain storage and route alignment ensures no increase in flood risk up or downstream. Replacement floodplain storage will be created within Park Hall nature reserve which increases flooding on the western side of the nature reserve. The connections between the Dunlop Channel and the Plants Brook are retained without any changes to their hydraulic performance.

9.1.6 The area in the vicinity of the proposed Bromford tunnel has been identified as a location where the groundwater regime could be affected by the proposed design. Therefore initial numerical modelling of the existing groundwater regime around the Bromford tunnel portals has been undertaken to establish the potential impact of the proposed tunnel on groundwater levels. The Bromford tunnel east portal approach shows less of an impact when compared to the west portal (see WR-003-026), with a predicted ponding of up to 0.7m on the northern side and drawdown of up to 0.4m on the southern side. This is in an area where water strike information indicates existing groundwater levels are between 2 to 3m depth.

9.1.7 The initial groundwater modelling has indicated that there is the potential for the Bromford tunnel east portal to act as a barrier to groundwater through flow within the superficial deposits. However, it is recognised that the conceptual model and initial groundwater model are based on water strike data and that aquifer properties used are within the range of literature values but not proven on site. These important uncertainties will be investigated as part of the on-going design process to refine the conceptual and numerical model build properties.

9.1.8 Depending on the depth of groundwater proven from site investigation, the potential increase / drawdown on groundwater levels may result in a long term shallow groundwater level condition in areas adjacent to the portals. Suitable water-proofing will be provided to the structure to prevent water inundation. Groundwater drainage will be provided to mitigate impacts of the structure on groundwater flow and level.

9.1.9 The surface water management strategy for CFA25 ensures run-off generated by rain water falling onto the Proposed Scheme is collected, attenuated and discharged at a controlled rate. The strategy is designed to manage discharges generated by rain storm events with a 1% AEP plus a 30% increase in rainfall intensity to allow for changes in rainfall patterns due to climate change.

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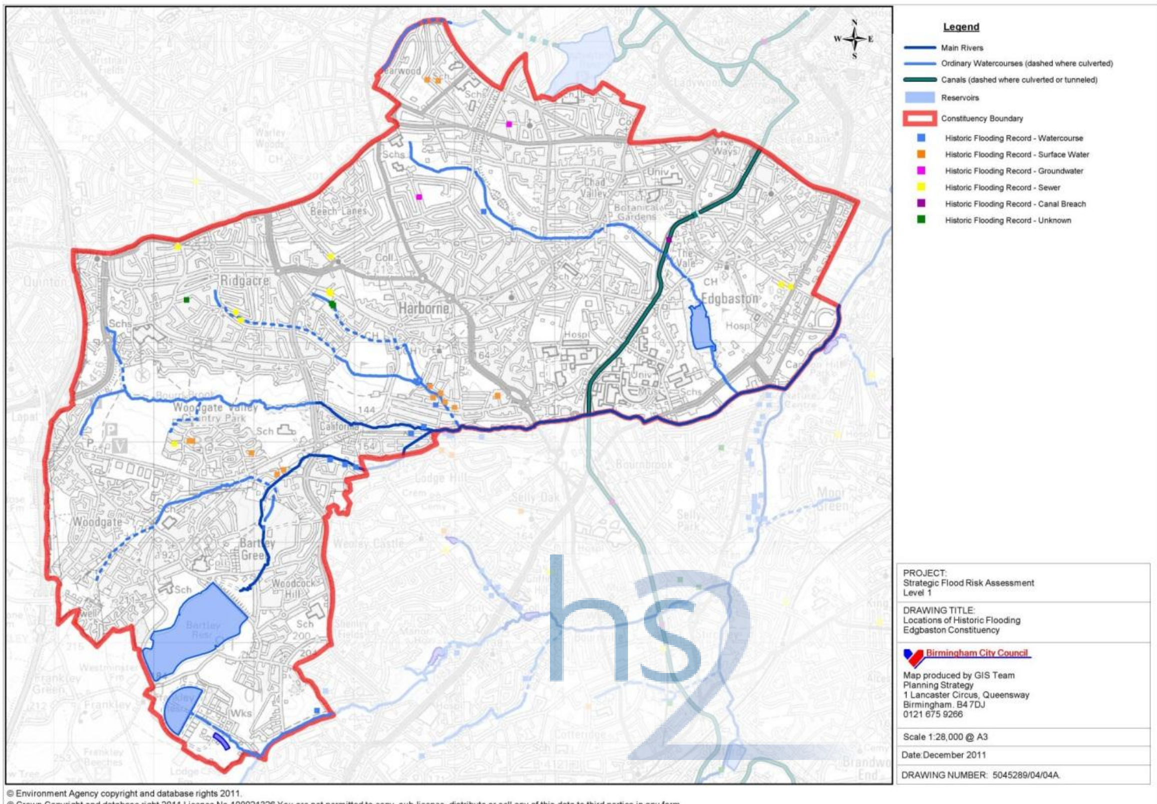
11 Annex A

11.1 Birmingham City Council SFRM location of historic flooding and water features



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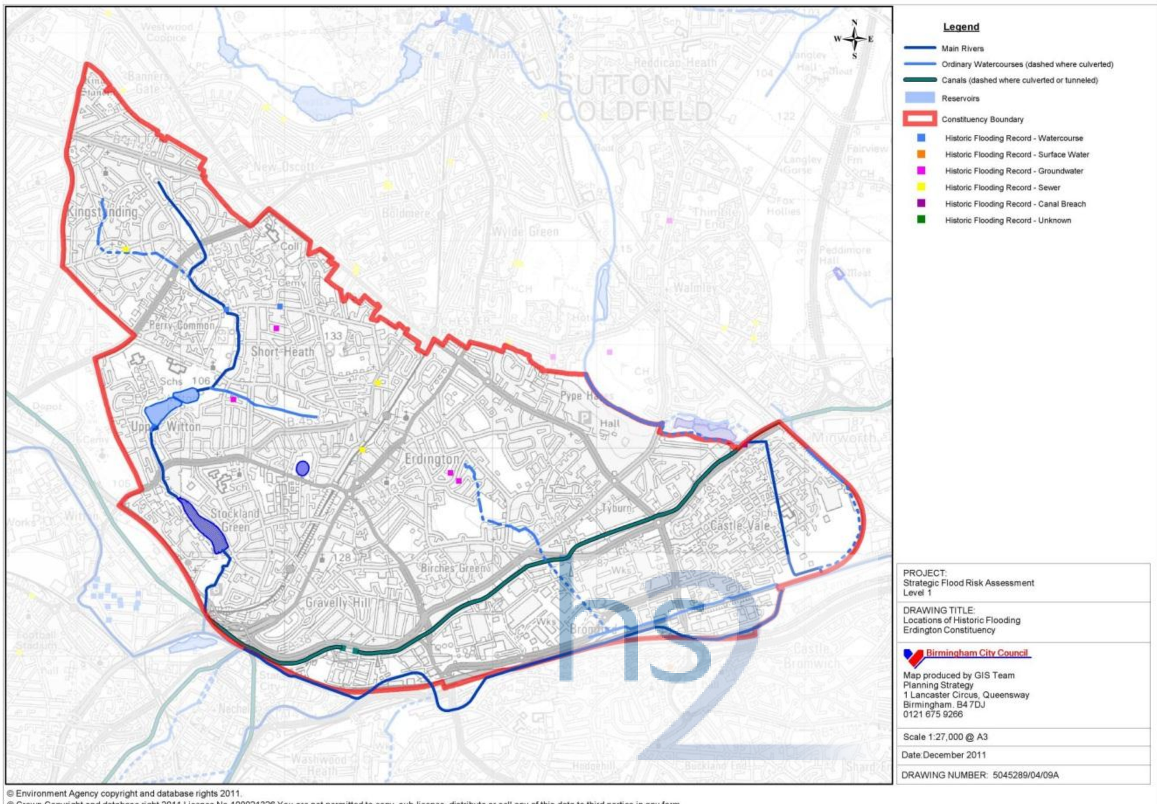

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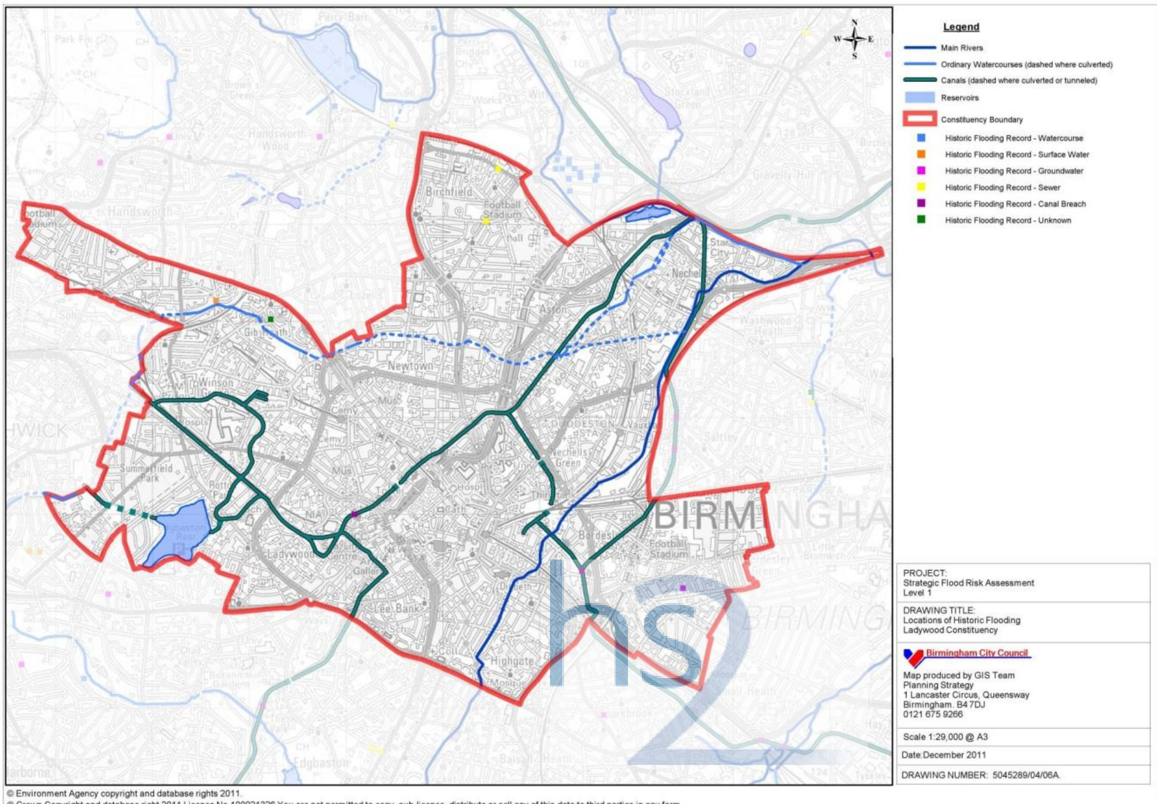

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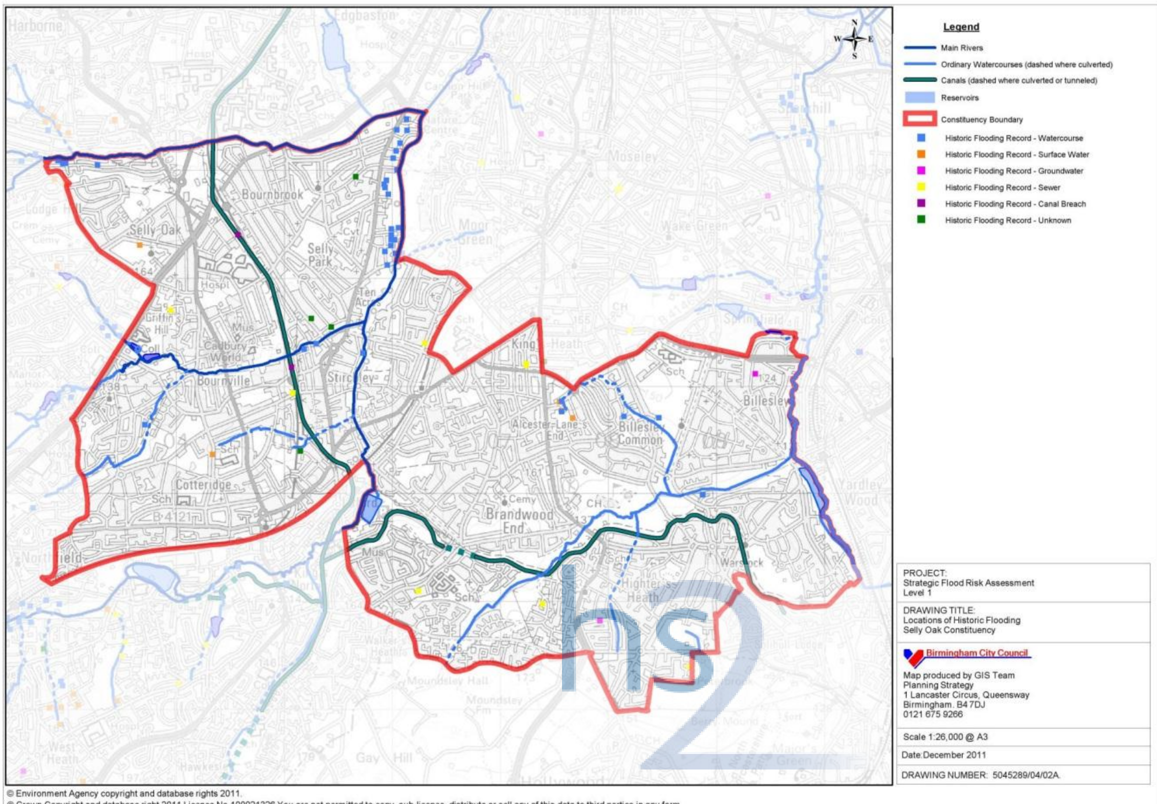

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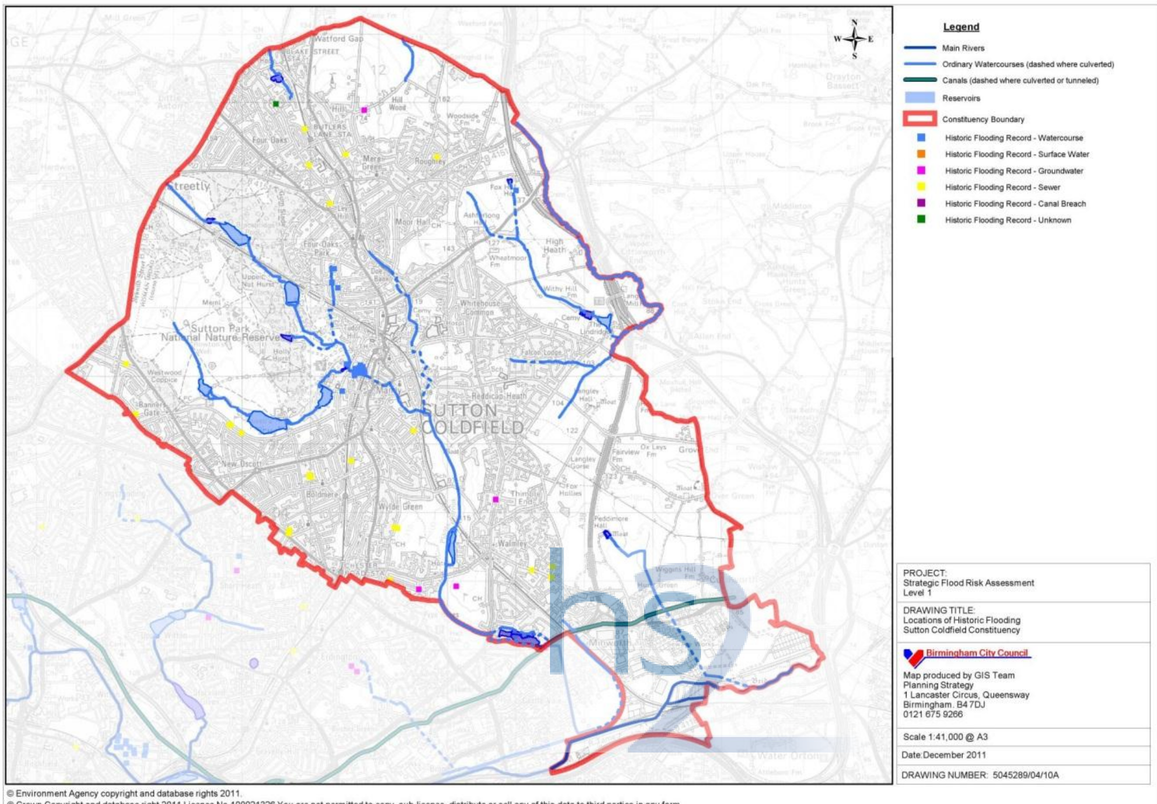

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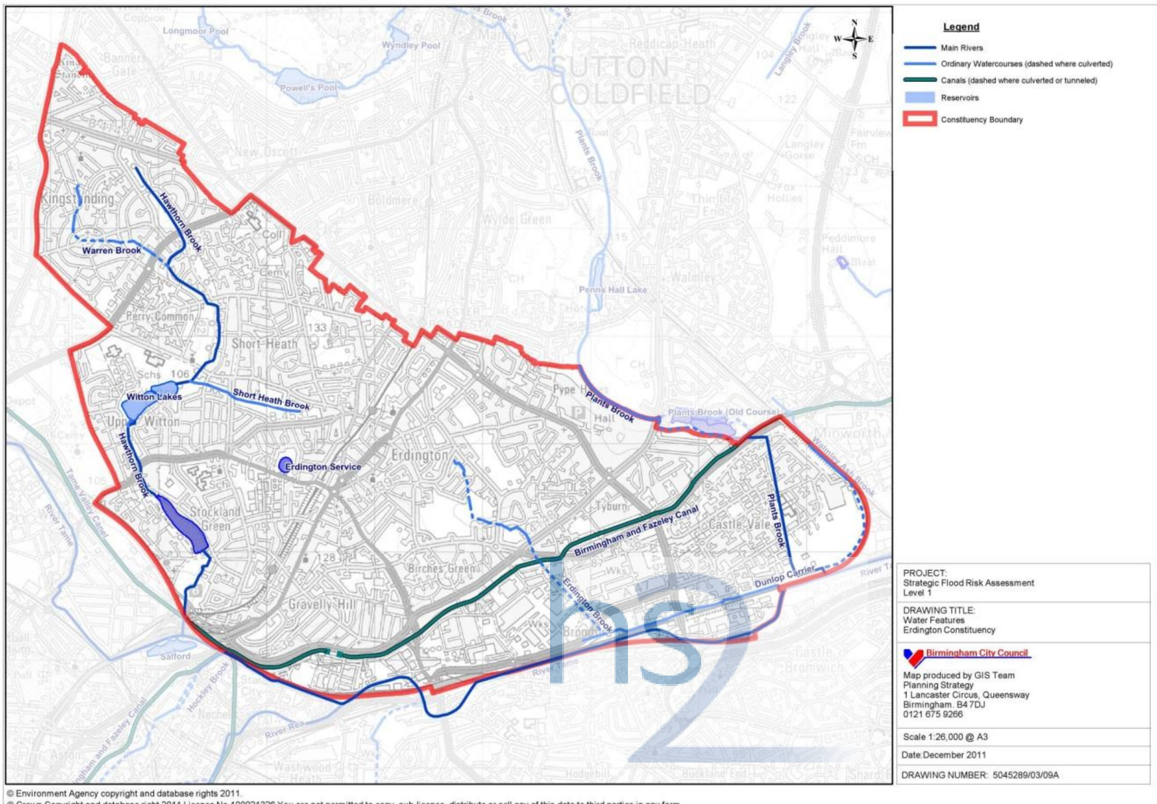

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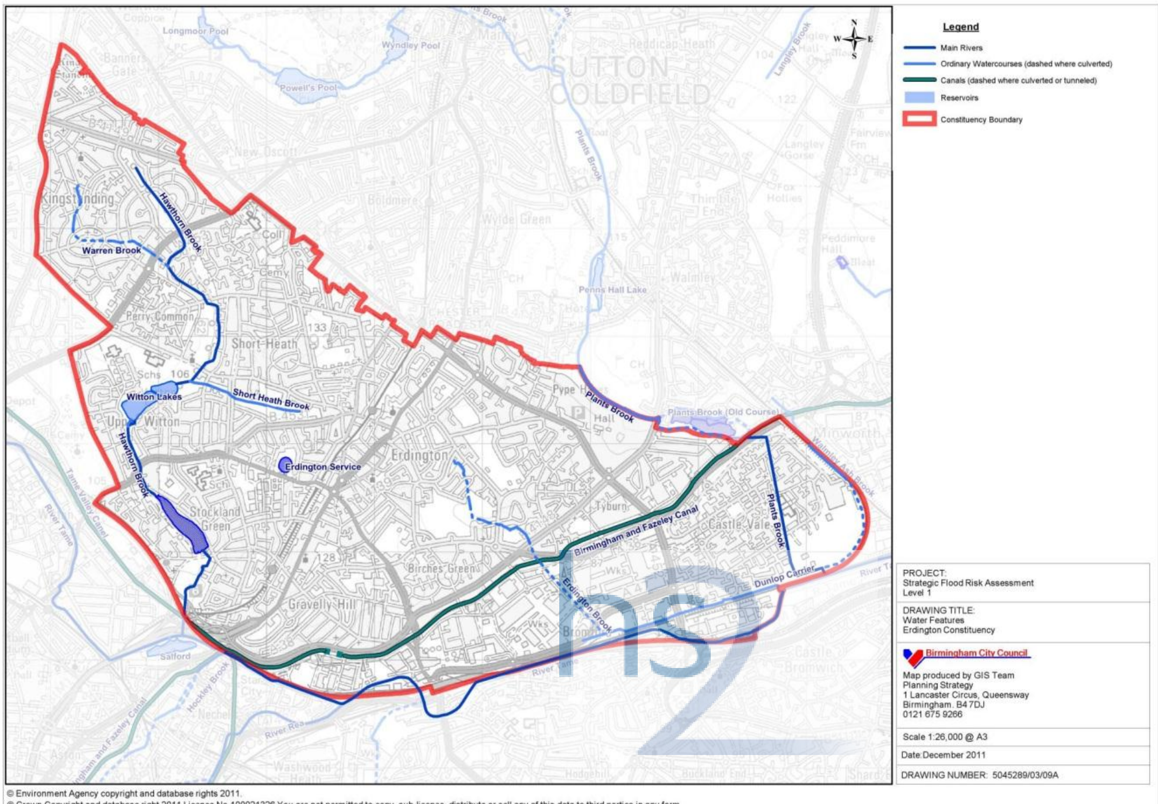

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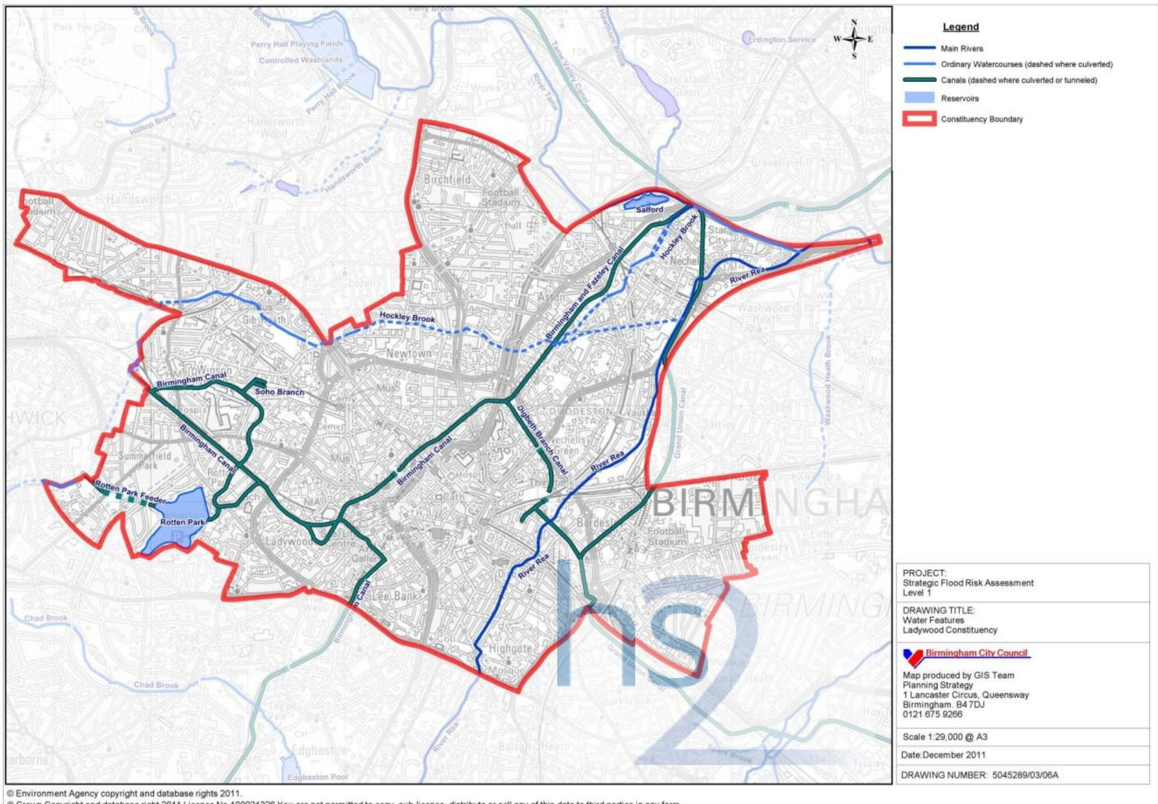

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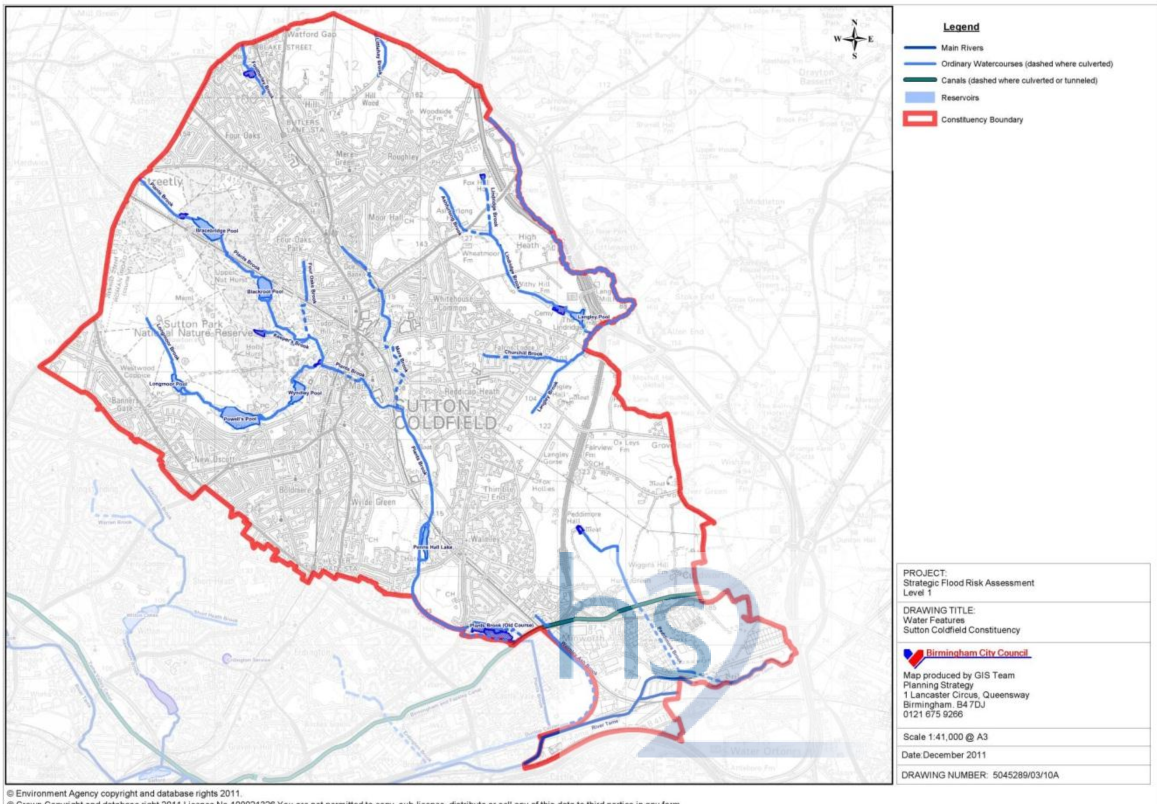

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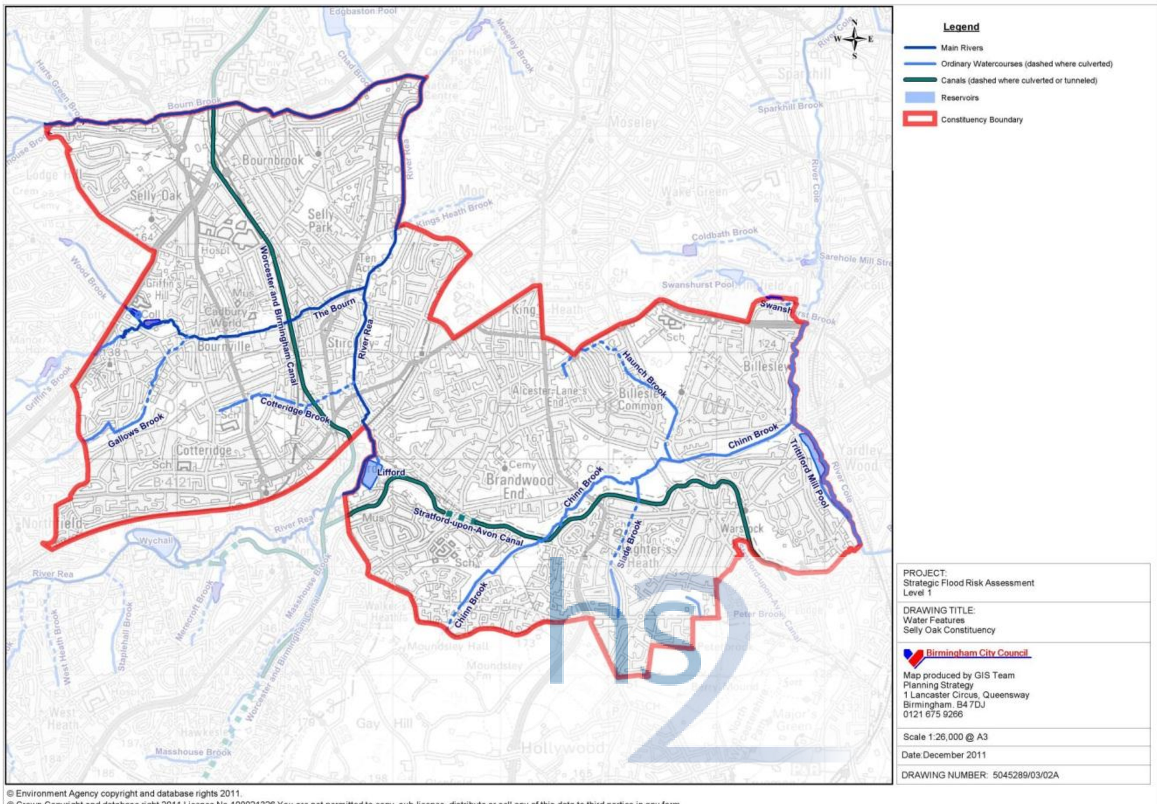

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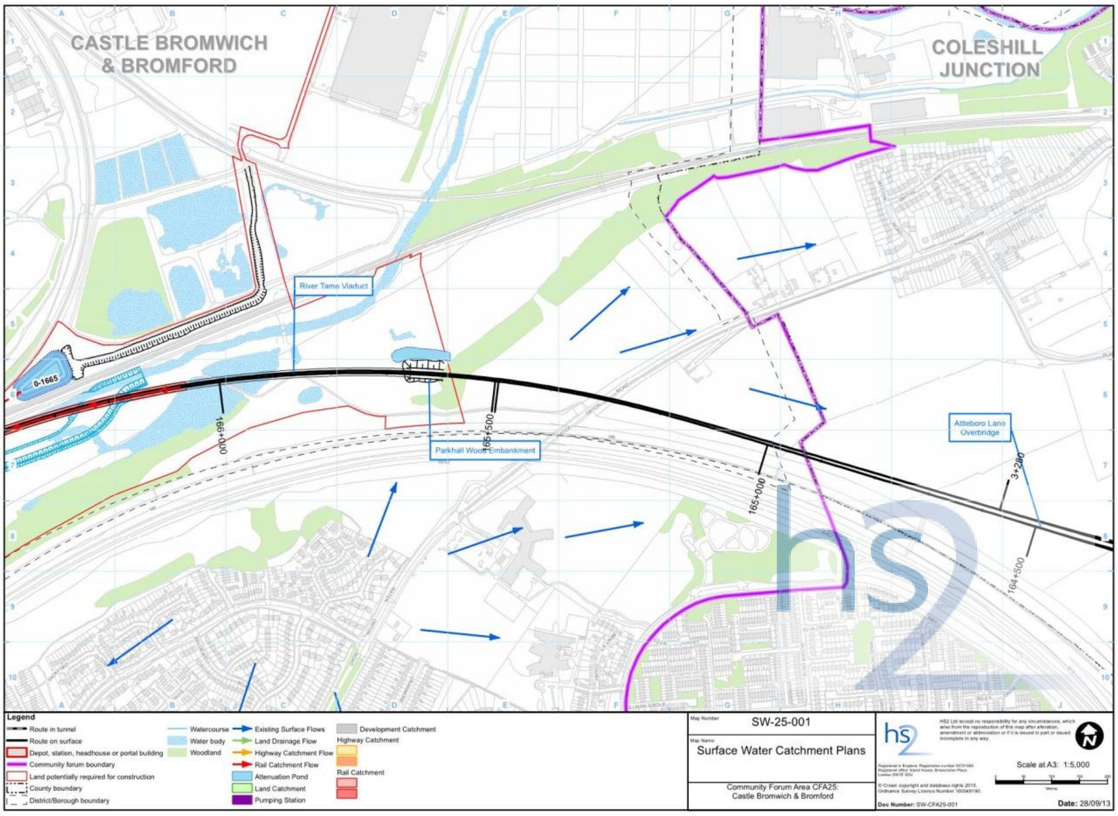
12 Annex B

12.1 Surface water catchment flow figures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COLESHILL JUNCTION
River Tame Viaduct
Parkhall Wood Embankment
Attleboro Lane Overbridge
Legend
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Community Forum Area CFA25: Castle Bromwich & Bromford
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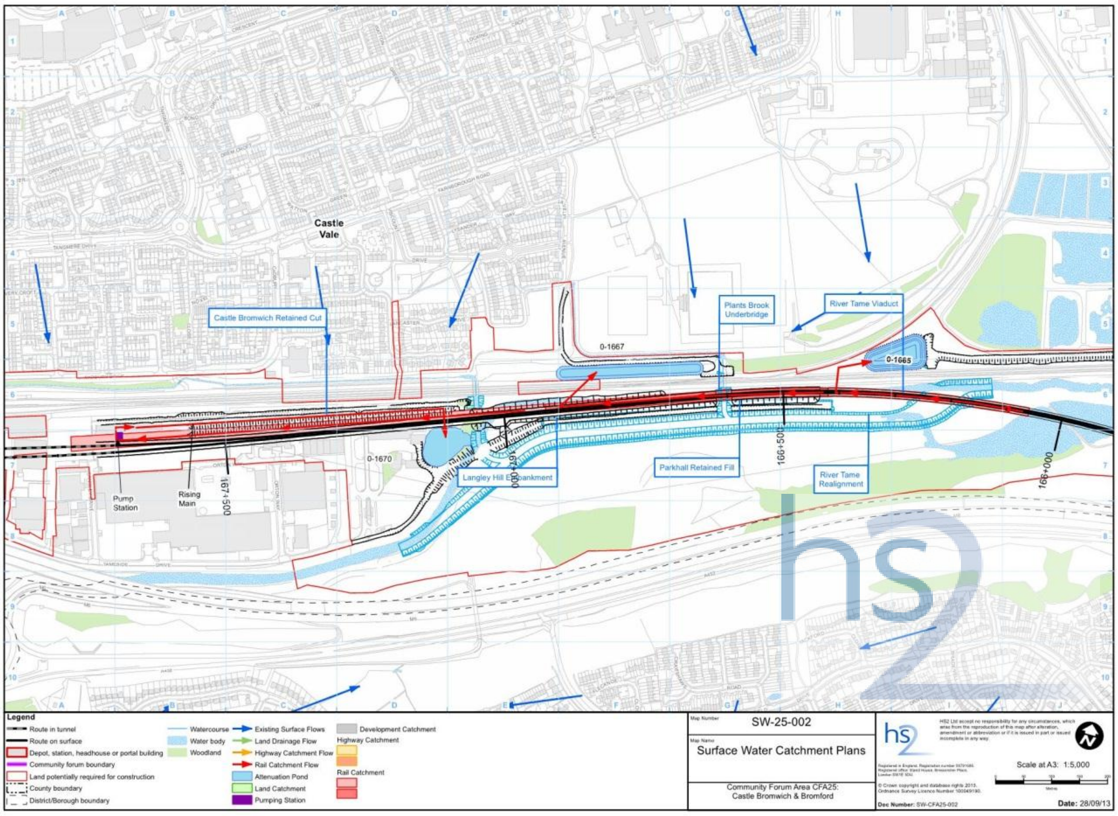
Date: 28/09/13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Castle Bromwich Retained Cut
Plants Brook Underbridge
River Tame Viaduct
Langley Hill Embankment
Parkhall Retained Fill
River Tame Realignment
Pump Station
Rising Main
Legend
SW-25-002
Surface Water Catchment Plans
Community Forum Area CFA25: Castle Bromwich & Bromford
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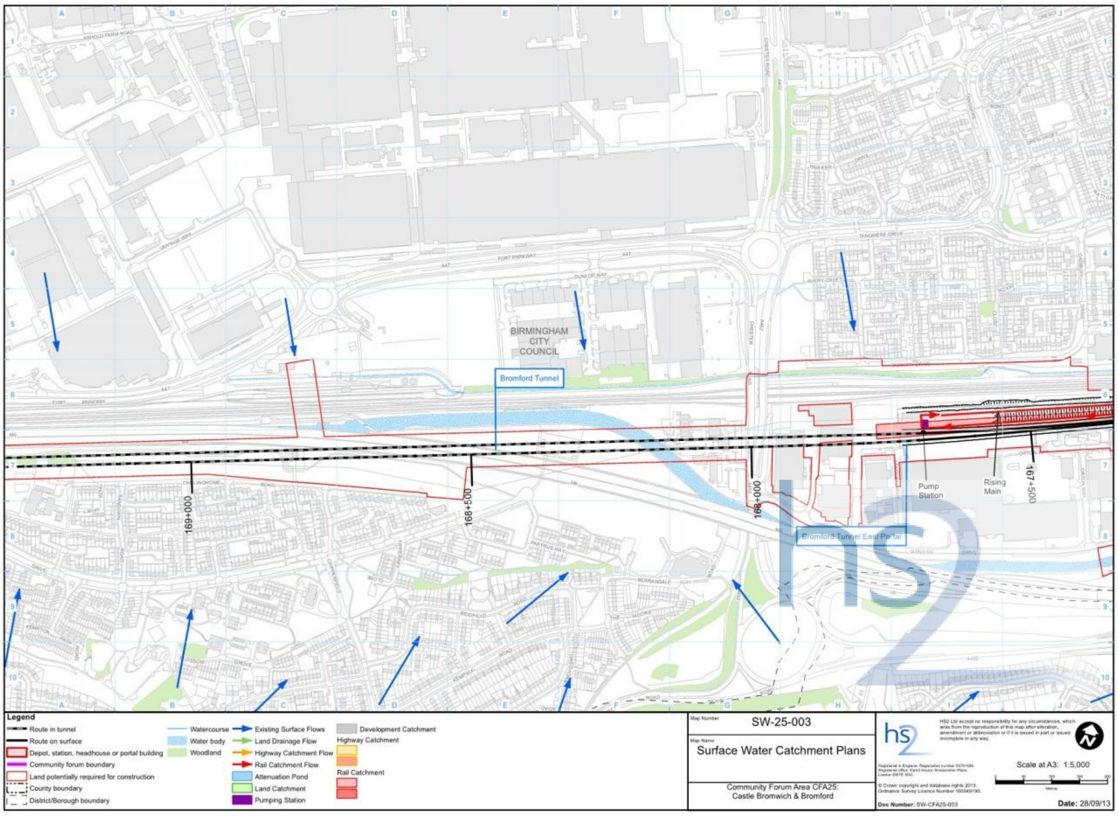
Date: 28/09/13


BIRMINGHAM
CITY
COUNCIL
Bromford Tunnel
169+000
168+500
168+000
167+500
Pump
Station
Rising
Main
Bromford Tunnel East Portal
Legend
Route in tunnel
Route on surface
Depot, station, headhouse or portal building
Community forum boundary
Land potentially required for construction
County boundary
District/Borough boundary
Watercourse
Water body
Woodland
Existing Surface Flows
Land Drainage Flow
Highway Catchment Flow
Rail Catchment Flow
Attenuation Pond
Land Catchment
Pumping Station
Development Catchment
Highway Catchment
Rail Catchment
SW-25-003
Surface Water Catchment Plans
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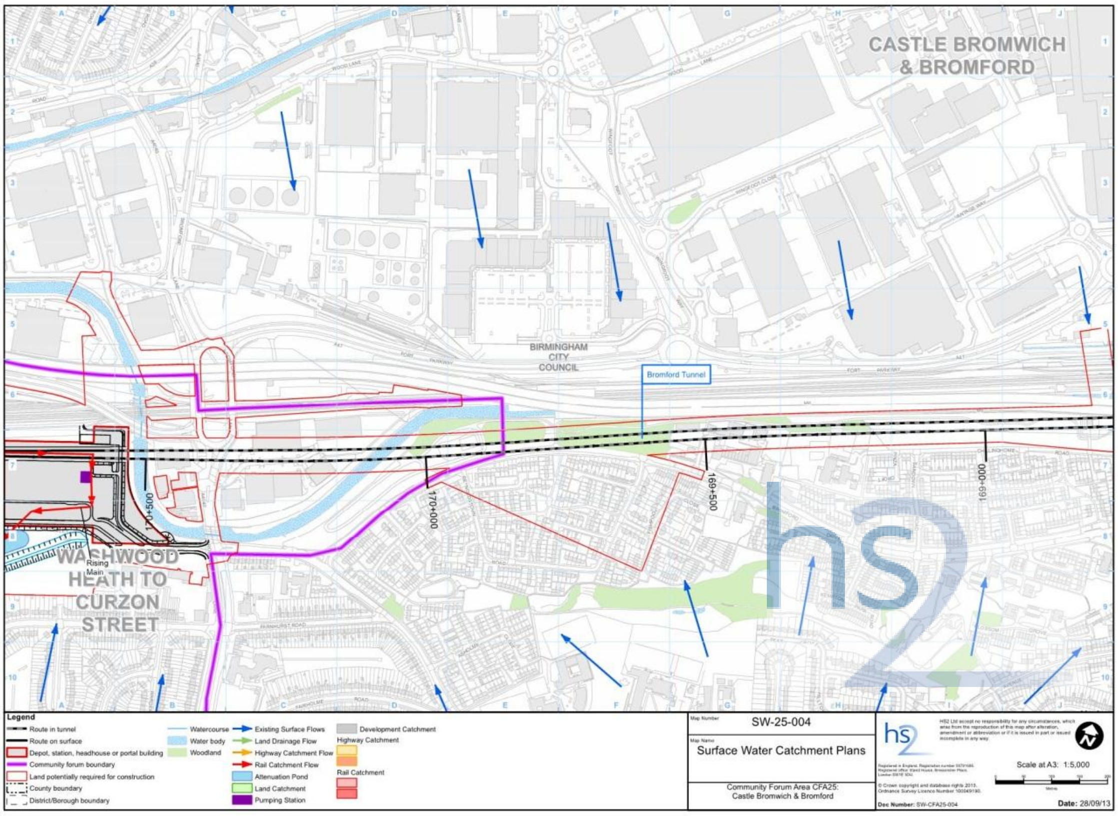
Scale at A3: 1:5,000
Date: 28/09/13


CASTLE BROMWICH
& BROMFORD
BIRMINGHAM
CITY
COUNCIL
Bromford Tunnel
170+000
169+500
169+000
Rising
Main
WASHWOOD
HEATH TO
CURZON
STREET
Legend
Route in tunnel
Route on surface
Depot, station, headhouse or portal building
Community forum boundary
Land potentially required for construction
County boundary
District/Borough boundary
Watercourse
Water body
Woodland
Existing Surface Flows
Land Drainage Flow
Highway Catchment Flow
Rail Catchment Flow
Attenuation Pond
Land Catchment
Pumping Station
Development Catchment
Highway Catchment
Rail Catchment
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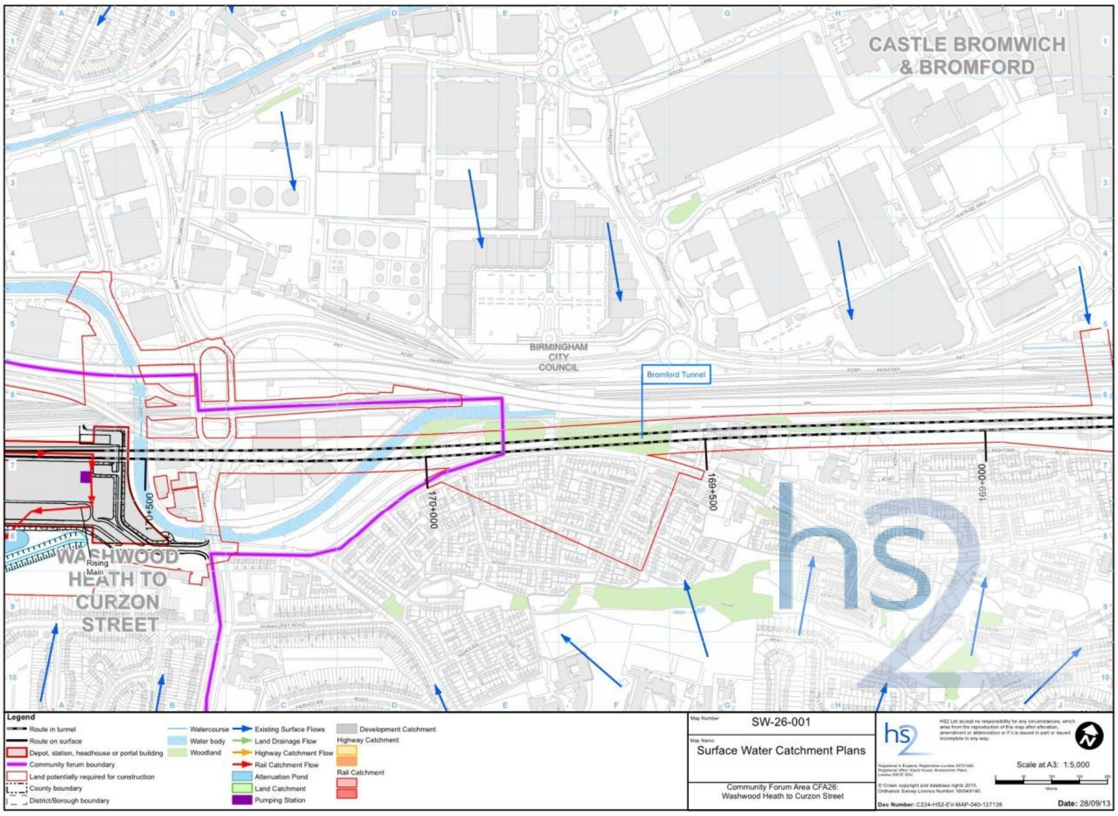
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BIRMINGHAM CITY COUNCIL
Bromford Tunnel
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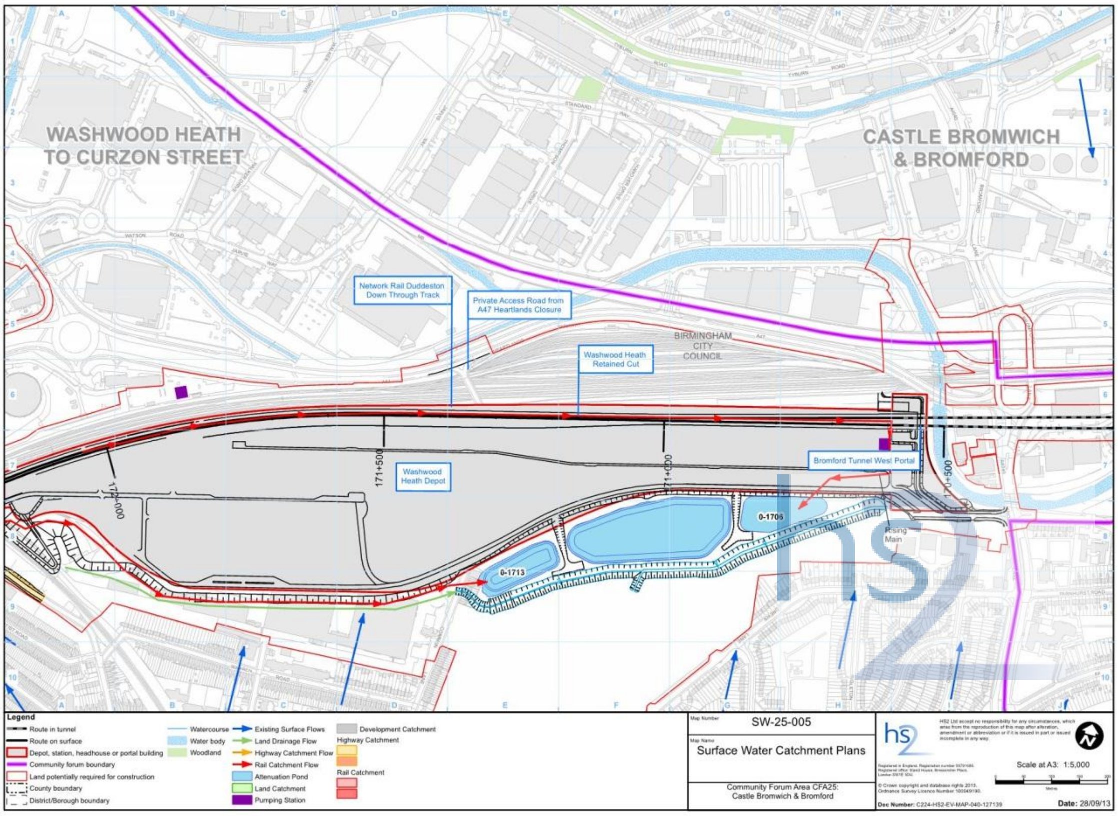
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CASTLE BROMWICH & BROMFORD
Network Rail Duddeston Down Through Track
Private Access Road from A47 Heartlands Closure
BIRMINGHAM CITY COUNCIL
Washwood Heath Retained Cut
Bromford Tunnel West Portal
Washwood Heath Depot
171+500
171+000
SW-25-005
Surface Water Catchment Plans
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